How We'll View Jupiter's Comet Crash

ASTRONOMY

June 1994 U.S. $2.95
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THE LOWELL OBSERVATORY STORY

Mars, Pluto & the Universe

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Moon Observer's Notebook

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- Merging Photos of Earth & Sky

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"For comet-hunting at Palomar I use the 18" Schmidt Camera. For personal observing I use the Meade 10" LX200 Schmidt-Cassegrain."—*David Levy*

Background photo: 18" Schmidt Camera, courtesy California Institute of Technology

Meade LX200 Schmidt-Cassegrains, the largest-selling serious telescopes in the world, are available in four apertures: 8"—$2295.; 10"—$2895.; 12"—$3995.; 16"—$14,950. Packing & shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 16"—$385. Contact your authorized Meade Advanced Products dealer for details.

A few words from a special Meade customer…

"With all of the attention that Comet Shoemaker-Levy 9 has been receiving lately because of the upcoming comet crash into Jupiter, I thought you might like to know the role that your company has played, not only in my development as an amateur astronomer, but also in many of the discoveries I've been fortunate enough to make.

My first Meade telescope, purchased in 1978, was your 4" f/15 refractor, an excellent instrument that gave me the finest images of Jupiter I had ever seen. As the years progressed, I have used the Meade 16" Starfinder Newtonian and 8" LX200. My current instrument is your 10" LX200. All of these telescopes show quality engineering, and all have performed extremely well in my observing programs. For all of its technical features, the 10" LX200 is probably the easiest telescope to use that I've ever observed with. I do not hesitate to recommend it.

I also use the LX200 to open up the skies for children; these programs are even more important to me than comet hunting. High-resolution telescopes like this can show the next generation that there is more to life than television.

Over the years I've acquired quite a collection of Meade accessories, especially eyepieces. You might be interested to know that all 7 of my visual comet discoveries were made using Meade eyepieces. Your Series 4000 eyepieces are superb, with the Super Wide 32mm (an incredible eyepiece) being a particular favorite of mine.

Beyond my own experience with Meade products, I continually hear good things from friends and colleagues about Meade Instruments as a company—that you're always "there" to back-up your product with after-sale service, advice, and support.

So to all of you at Meade Instruments, many thanks for your contributions to amateur astronomy and to this amateur astronomer in particular. If you'd like to reprint this letter, you have my permission. Everything I've said comes from the heart.

With all best wishes,

David H. Levy

See David at these events on *The Great Comet Crash Tour:*

April 25, 7:30PM: Flandrau Science Center and Planetarium, University of Arizona, Tucson AZ; 602-621-4515.

April 29, 8:00PM: Miami Space Transit Planetarium, Miami, FL; 305-854-2222.

May 4 (observing), **May 5** (lecture): Kansas City Museum Planetarium, Kansas City, MO; 816-483-8300.

May 16, 7:30PM: Griffith Observatory and Planetarium, Los Angeles, CA; 213-664-1191.

May 21, 8:00PM (lecture); **May 22, 1:00PM** (daytime star party): Cranbrook Institute of Science, Bloomfield Hills, MI; 313-654-3200

May 23, 7:30PM: American Museum-Hayden Planetarium, New York, NY; 212-769-5900.

May 24, 8:00PM: Fairfield County Astronomical Society, Stamford, CT; 203-721-9529.

May 25, 8:00PM: Astronomical Society of Greater Hartford, Hartford, CT; 203-721-9529.

June 11, 7:30PM: Newcombe Theatre, Royal B.C. Museum, Victoria, British Colombia, Canada; 604-387-5745.

June 12, 1:00PM: Dominion Astrophysical Observatory N.R.C., Royal B.C. Museum, Victoria, B.C., Canada (children only); 604-387-5745.

June 13, 8:00PM: Star Theatre, H.R. MacMillan Planetarium; Vancouver, B.C., Canada; 604-736-4431.

June 14, 8:00PM: Lecture Hall, H.R. MacMillan Planetarium; Vancouver, B.C., Canada; 604-736-4431.

June 23, 7:15PM: Koch Science Centre and Planetarium, Evansville, IN; 812-425-2406.

June 24, 8:00PM: Cleveland Museum of Natural History, Cleveland, OH; 216-231-4600.

July 10: Fels Planetarium, Franklin Institute Science Museum, Philadelphia, PA; 215-448-1208.

July 21: "Jupiter Watch Party" with The Planetary Society, U.S. Naval Observatory, Washington, DC; 818-793-5100, for pass information.

July 22: "Jupiter Watch Presentation" with The Planetary Society, Carl Sagan, Carolyn & Eugene Shoemaker; Stouffer Mayflower Hotel, Washington DC; for tickets: 818-793-5100.

August 5 - 6: *STARFEST* star party, Mount Forest, Ontario, Canada; 416-761-1798.

August 27: Lecture and observing at The Pacific Observatory, Blackcomb Mountain, Whistler, B.C. Canada; 604-932-3141.

For information on additional appearances and book-signings David Levy will be making, call **1-800-227-1114.**

Comet Shoemaker-Levy 9 is composed of at least 20 separate fragments, all of which will impact Jupiter's surface between July 16 - 22, 1994.

photo by James V. Scotti, *Spacewatch*

One of the world's most renowned amateur astronomers, David Levy began his astronomical career at age 12 and has since discovered or co-discovered 19 comets, including Shoemaker-Levy 9, scheduled to crash into Jupiter in July. He has authored over 200 articles for major scientific magazines; his books include *The Quest for Comets* and *Skywatching,* both just published; and *An Observing Guide for Comets, Asteroids, Meteors, and Zodiacal Light* (with S. J. Edberg). David has served as an observer with the Planetary Science Institute; currently he is a senior instructional specialist at the University of Arizona's *Project ARTIST* and an observer with the Palomar Asteroid and Comet Survey.

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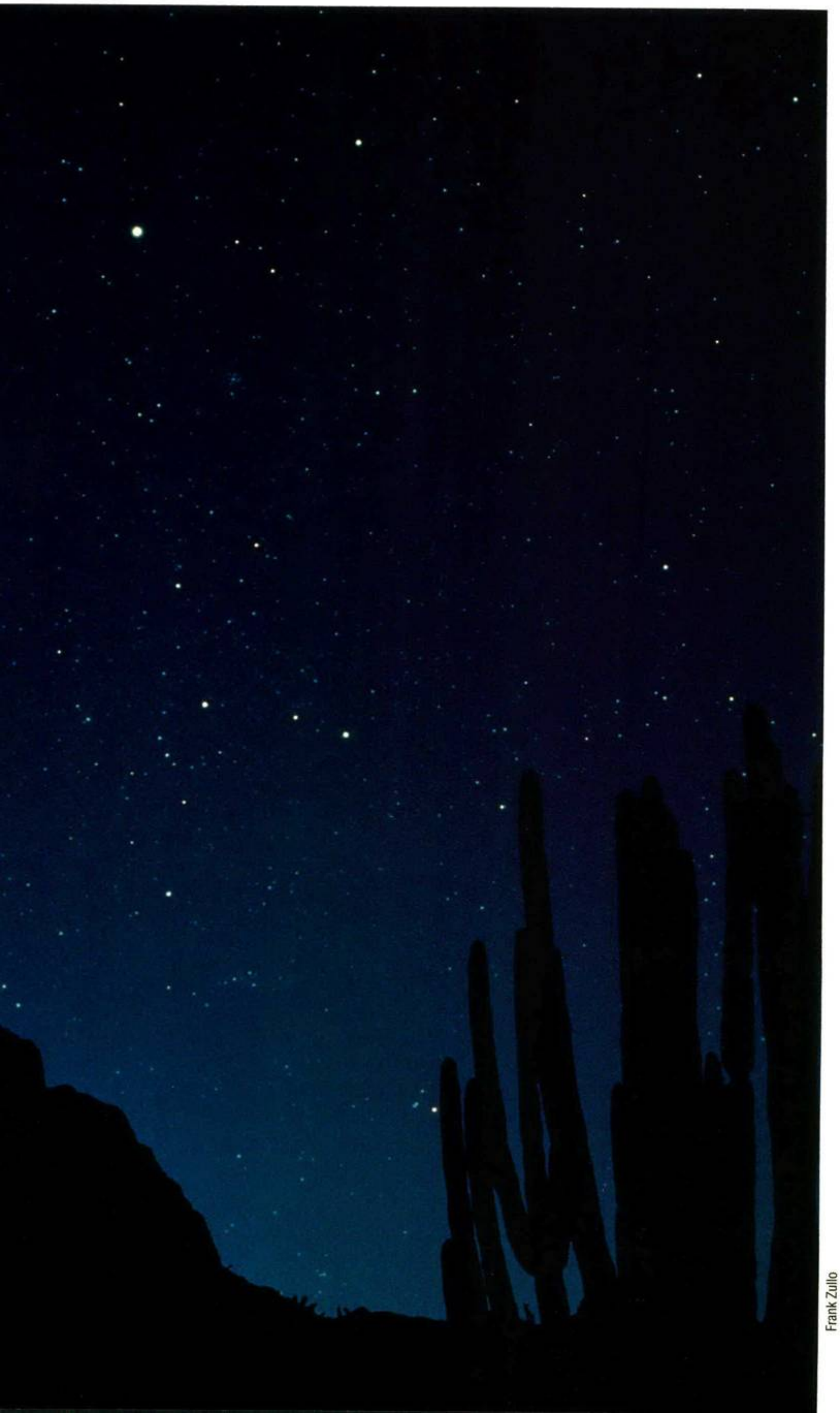
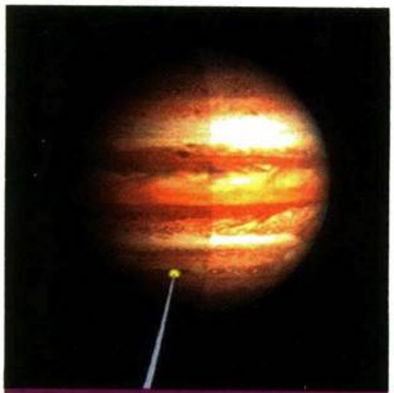
ASTRONOMY



Frank Zullo



Astronomy: Steven Davis; Jupiter image/NASA

40
Countdown to the Big Comet Crash

Bill and Sally Fletcher

62
Wonders of the Milky Way

Jean Dragesco

72
Combining Earth and Sky

28 **100 Years on Mars Hill**

They mapped Mars, discovered Pluto, and explored galaxies. In these and other ways, the astronomers at Lowell Observatory helped push back astronomical frontiers. By Bruce Bond.

Bruce Bond

40 **Countdown to the Big Comet Crash**

Astronomers eagerly anticipate Comet Shoemaker-Levy 9's collision with Jupiter to see what nature's probe can tell them about the giant planet. By David Bruning.

46 **Sky Almanac**

Venus dominates the evening sky in June, reaching its peak altitude while visiting the Beehive star cluster. By Deborah Byrd and Rick Shaffer.

Palomar Observatory

56 **Tracking Down a Quasar**

Get out your 8-inch or larger telescope and stalk this elusive starlike prey. By Phil Harrington.

62 **Glittering Realms of the Summer Milky Way**

It's a visual feast touring the summer's best clusters and nebulae. With naked eye, binoculars, or small scope, stroll through the constellations Cygnus, Aquila, and Sagittarius. By David J. Eicher.

70 **Exploring Mare Humorum**

A small telescope will reveal the mountains, craters, and rilles of an ancient lunar impact basin. By Michael T. Kitt.

72 **Joining Land and Sky**

Combine beautiful photos of the night sky with earthly foregrounds to create breathtaking images. By Frank Zullo.

DEPARTMENTS

6 **Behind the Scenes**
- Mr. Lowell's Observatory — and Yours

6 **Letters**

14 **Viewpoints**
- After a shaky start we had a nice party. . .

18 **AstroNews**
- Inside the Helix
- Novel Approach Suggests Universe Is Open
- Screams from a Distant Star
- NASA Issues Mars Recovery Plan
- Herschel's Double Stars Revisited
- New Scope on Kitt Peak
- First Asteroid Moon Found
- Clementine's First Images

22 **Amateur News**
- Explore the Universe in Flagstaff
- Amateurs Restore Carnegie Telescope

81 **Reader Reports**
Tricolor CCD Imaging Under the Light of the Full Moon

86 **Astronomy Books**
Matter in the Universe: *Through the Universe Darkly*

92 **New Products**
- A Low-Cost CCD Camera
- An Intelligent Drive Corrector
- Premium Optical Assemblies and Mounts

94 **Meetings and Events**

98 **AstroBytes**
Processing Your Astro-images with MIRA

104 **Advertiser Index**

106 **Readings and Credits**

COVER

WISPY TENDRILS OF RED NEBULOSITY highlight our Galaxy's stellar nurseries. The summer sky is home to many of these spectacular nurseries, as well as the beautiful star clusters they eventually become (see page 62). Photo of the Omega Nebula by amateur astrophotographer Michel Stecker.

BEHIND THE SCENES

Mr. Lowell's Observatory — and Yours

Percival Lowell did something that a lot of amateur astronomers do at some point. He built an observatory. However Lowell's was not just any observatory — after all, few of us would outfit one with a 24-inch Clark refractor. Lowell's wealth let him build on a grand scale. But if all we see in him is a rich man indulging a hobby, I think we miss the most important part.

What drove Lowell was a passion — to prove the existence of life on Mars. His passion was frustrated because Martians don't exist. But his search led the observatory he founded (see page 28) into real discoveries, for his other big passion — finding Planet X — succeeded. Pluto actually *did* exist. Despite differences in scale, Mr. Lowell's Observatory was born out of the same impulses that drive you and me to view the sky. While we may never make great discoveries, we can share in the sense of boundless adventure that drove Lowell and others like him.

Joining the Lowell Observatory story is one on Comet Shoemaker-Levy 9. Associate editor Dave Bruning attended a science workshop earlier this year where he saw and heard about the observations planetary astronomers (including many at Lowell Observatory) will undertake when the Great Comet Crash comes. His report, which includes the latest estimates of collision times, begins on page 40 — don't miss it.

Elsewhere in this issue, you can take a trip along the Milky Way. From now into the chill of autumn, most of the Home Galaxy's best deep-sky objects will parade overhead every night. Starting on page 62, you'll find an illustrated guidebook to these beautiful, must-see sights, as captured by some of the best astrophotographers going. Experienced observers can revisit old friends, and newcomers have glorious things to discover. And when growing moonlight starts to drown out the Milky Way — well, why not look at the Moon? On page 70, backyard selenographer Michael Kitt opens the Moon Observer's Notebook to the Mare Humorum page and takes you on a trip to explore its hills and rilles. And to bring you down to Earth, take a look on page 72 at what Frank Zullo has to show. But be careful. His photographic technique is frankly a little dangerous. It lets you commit impossible frauds — but you can also create images of overwhelming beauty. Like any fine tool, the technique needs care and judgement. Are you up to the challenge?

Finally, I'd like to take a moment to note the retirement of ASTRONOMY's publisher, Bob Maas, who joined the magazine in 1977. Bob has very ably steered its financial and business details all these years and provided invaluable guidance to all of us at the magazine, especially myself. And in his replacement, Russ Larson, ASTRONOMY has a publisher who will continue in the same fine spirit. The future looks very bright indeed.

Sincerely,

Robert Burnham

Robert Burnham
Editor

LETTERS

Murmurs of the Big Bang

After reading Richard Talcott's intriguing "Everything You Wanted to Know About the Big Bang" (January 1994), I cannot help but feel our understanding of the beginning and early history of the universe is quite limited. It seems clear that we should accept that the universe exists, and because it is impossible to create something out of nothing, some thing existed prior to our present universe.

The Big Bang may still be our best bet, but let us seek alternatives that may help us better understand the confounding challenges of the beginning. — *Albert J. Fido, Gwent, South Wales, Great Britain*

Your editorial comments on cosmology, particularly those in Mr. Talcott's article, are very astute. However, the final sidebar in that article is misleading. The Big Bang theory is anything but simple. In fact it abounds with convoluted reasoning. The theory is mathematical and is not based on observational phenomena.

Now that you have stroked the egos of academe, why not present articles on other theories of cosmology? How about the plasma theory of cosmology put forth by Hannes Alfven and Ilya Prigogine? You owe it to your readers to present the other side of the question. — *Robert McKay, Canal Flats, British Columbia, Canada*

I thought that Alan Guth's inflationary theory predicted that the universe, when it was the size of a proton, underwent a microsecond period of expansion — at the speed of light — to about the size of a grapefruit. Unless inflationary theory has changed in the last few years, this seems to make more sense than the universe expanding several hundred billion light-years in a fraction of a second, as stated in the article. Should space not be

(continued on page 12)

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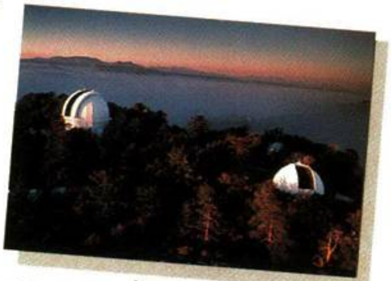

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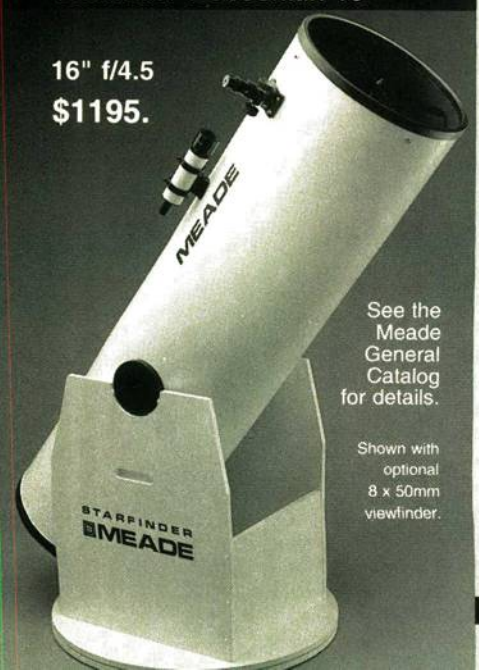

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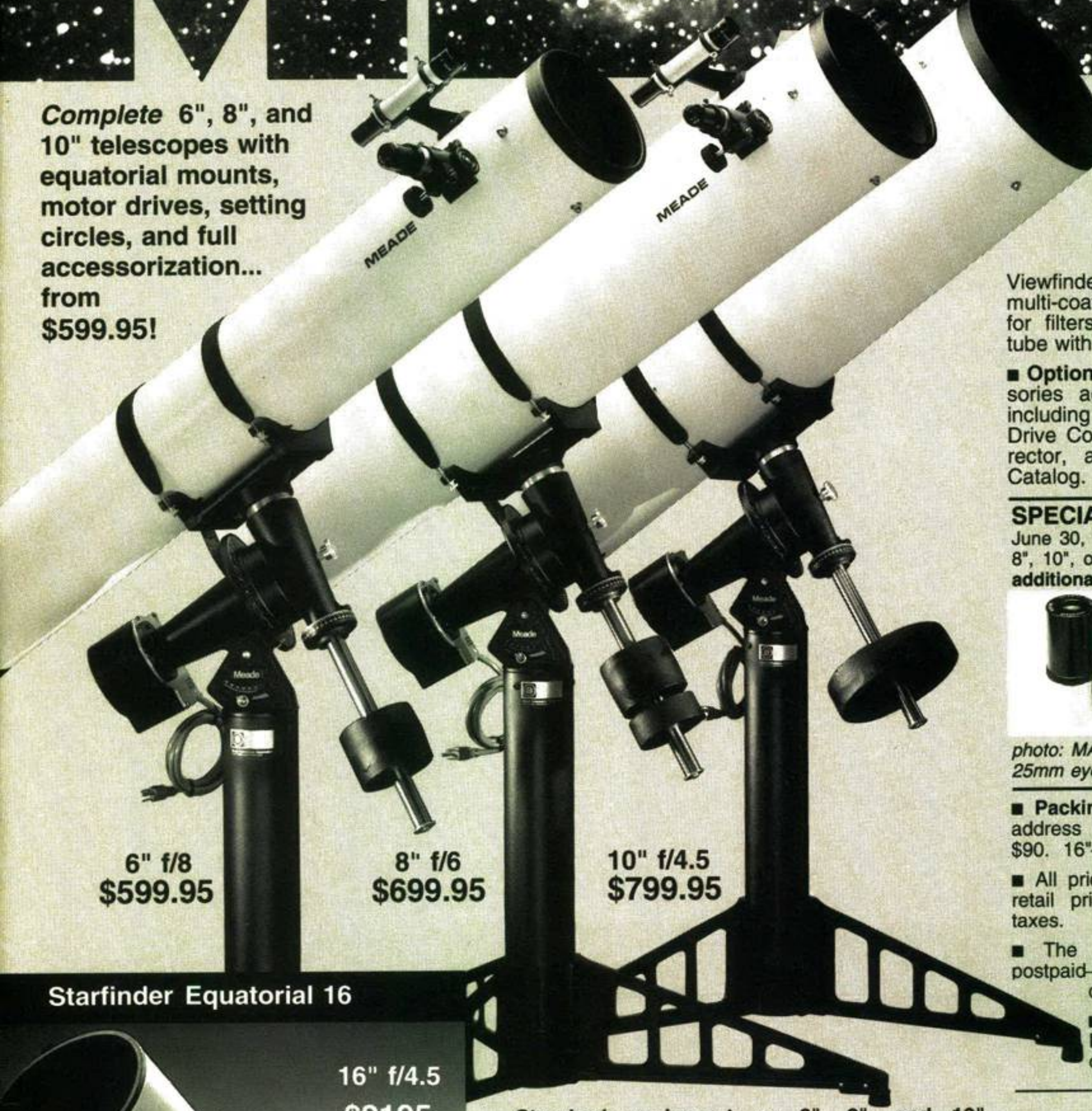

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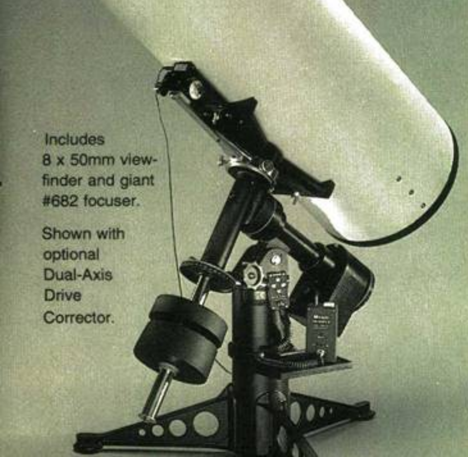

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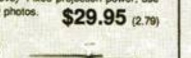

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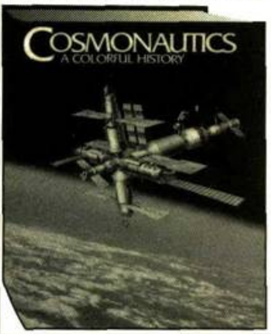

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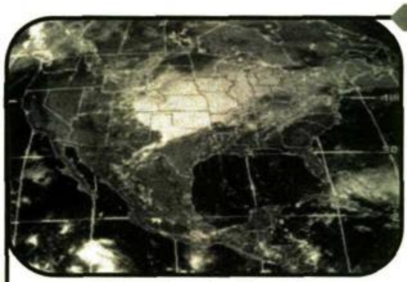

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confined by special relativity at this time? It is not empty, and its energy should be constrained by the limit of traveling faster than light. — *Sean Brimm, North East, Maryland*

— Guth's original model implied that the universe expanded from about the size of a proton to that of a grapefruit in roughly 10^{-32} *second (one hundred thousand billion billion billionths of a second). In the 13 years since Guth's model, however, physicists have refined the theory and now lean more toward the figures quoted in the article. For alternative hypotheses, see "Beyond the Big Bang" (April 1992).*

To Be or Not to Be?

Having read C. Renee Beveridge's article "So You Want to Be a Professional Astronomer?" (February 1994), I feel compelled to respond. It's tragic that Ms. Beveridge did not go on to get her doctorate in astronomy. I can sympathize with her sense of discouragement, having been through my own trials in obtaining a Ph.D. in philosophy.

While Ms. Beveridge's advisor told her to get out of the field if her heart wasn't in it, do feelings of discouragement and disappointment really mean her heart isn't in it? I'm sure that Henrietta Leavitt and Annie Jump Cannon went through periods of great discouragement. Had they quit we might not understand the universe as we do today. — *Anthony Russell, Beresford, New Brunswick, Canada*

As a doctoral student at the University of Toronto, I identified strongly with the points raised by C. Renee Beveridge. I am a linguist working on the relationship between theoretical syntax and language acquisition. Many are the times I have bemoaned the loss of a deep love of language and matters linguistic.

Is the pressure to publish or perish and establish one's name so overwhelming that our professors and mentors must focus on narrow sub-specialties to the exclusion of the overall picture? Are we destined to lose sight of the grandeur of the forest by peering at a small part of one tree? A friend of mine says in the world of graduate study you learn more and more about less and less until you end up knowing everything about nothing.

It seems that losing dedicated and intelligent people like Ms. Beveridge impoverishes the scientific community and speaks volumes about the problems of modern day academe. — *Phil Gurski, University of Toronto, Toronto, Ontario, Canada*

Desert Meteor Watch

What a wonder it is to sit in the middle of a desert way out on the Arabian peninsula under dark skies and watch the stars! We had a terrific time viewing the Geminid meteor shower on the morning of December 14, 1993.

Expecting to see maybe two meteors per minute, we were almost breathless at the spectacle before us. "Hey — wow —look over there — another — no — over here — you missed it!" It was a nonstop show. Several bright meteors traversed more than halfway across the sky. During the best half hour we saw an average of more than five meteors per minute. Things won't be quite the same when we go home to Canada, but we'll keep watching. — *Dr. and Mrs. L. Kwantes, Muscat, Oman*

Shoemaker-Levy 9 and Jupiter Info Available

Please inform backyard astronomers that I am making available an informational package regarding the collision between Comet Shoemaker-Levy 9 and Jupiter and will be collecting observations and distributing them. For a copy of the package, please send $2 to cover postage along with each request. — *Steve H. Lucas, 14400 South Kolin Ave., Midlothian, Illinois 60445*

Project Tombaugh?

I enjoyed Robert Burnham's article "Pluto and Charon: At the Edge of Night" (January 1994). The proposed Pluto Fast Flyby mission sounds fascinating. But I think it has been misnamed. Why not call it Project Tombaugh, to honor the planet's discoverer? — *Dennis Barnes, Sumter, South Carolina*

Clementine Trajectory Correction

"The Moon Miner's Daughter" (February 1994) states that astronomers at NASA's Goddard Space Flight Center designed the complex trajectory for getting the Clementine probe to the Moon and to asteroid Geographos. Although Goddard's computer resources were used and they provided a management channel for funds from the Naval Research Laboratory, the basic trajectory was developed in early 1992 by my orbit-design section at Computer Sciences Corporation in Lanham, Maryland. — *David W. Dunham, Laurel, Maryland* □

ASTRONOMY welcomes suggestions and additional information about articles and astronomy in general. Send your letters to ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187-1612, or on Internet use 72000.2704@CompuServe.com. Letters may be edited for length and clarity.

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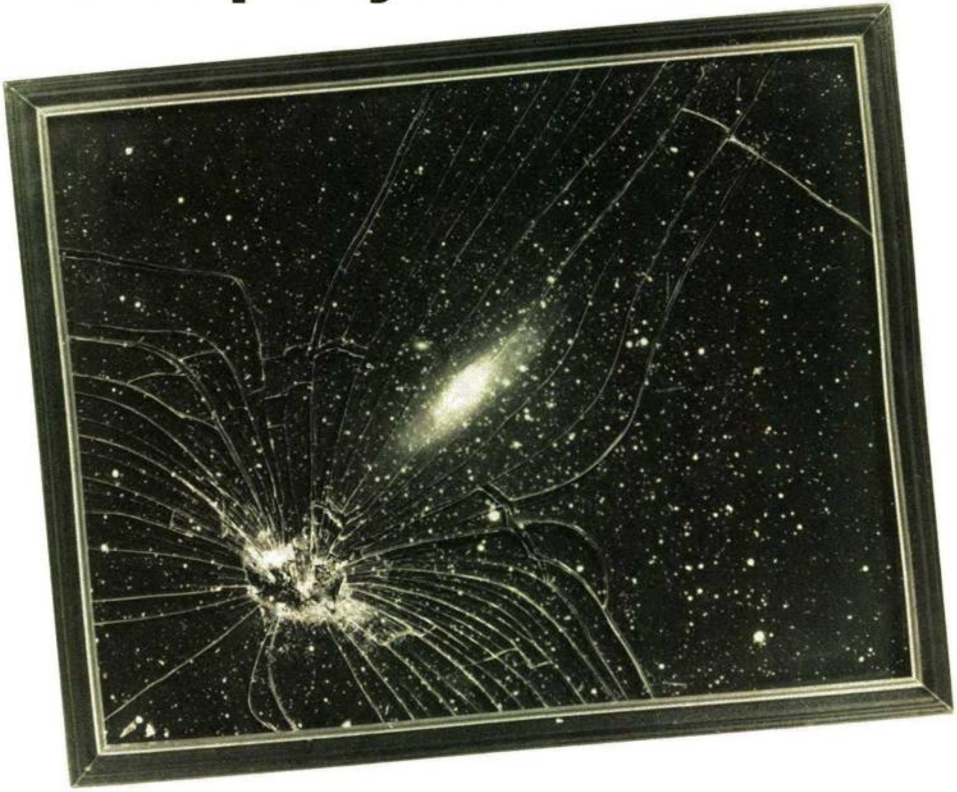
VIEWPOINTS

After a shaky start, we had a nice party. . .



by Michael Chibnik

There are moving experiences, and then there are MOVING experiences. One could best describe my morning of January 24 as one moving experience that lead to another. Far below my hometown of Simi Valley, California, a "blind fault" shifted, sending seismic waves of energy throughout Southern California. Like a giant geologic alarm clock, the quake rousted our neighborhood out of bed for what would turn out to be a rendezvous with the universe.

The first jolt shook my wife, Robin, and me awake with, to put it mildly, a start. The noise was terrific: a wild cacophony of windows rattling, china and glasses breaking, books, stereo, and TV equipment crashing. Quick, I thought, turn on the lights . . . no electricity! In a flash Robin, who was closest to the hallway, got to the kids' rooms to see if they were okay. Then the second major tremor hit. In our darkened house, wall-mounted photos leaped into the air and crashed to the ground with crunching sounds. Our large plate-glass mirror broke away from its support in a shattering crescendo. As the tremors subsided, everyone bolted for the front door.

After seeing to it that everybody was out of the house, I dashed back inside to get some flashlights and warm clothing for my family. Before making a final exit of the house, I sniffed for signs of a ruptured gas line. No gas odor, but the smell from the kitchen foretold a major cleaning effort when all was over.

Outdoors the scene felt a little unreal, as though out of the "Twilight Zone." The tremors had stopped; it was quiet. Warm winds coming down from mountains to the east took the chill out of the predawn air. Since the power was out throughout the city, it was pitch black.

A familiar voice pierced the shadows: "Hi, Mike!" It was Evon Roy, my neighbor from across the street, who was standing with his wife and other people from the neighborhood. Our family felt its way over to a grouping of silhouettes milling about in the darkness. Once everyone greeted and hugged one

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another, grateful for getting through the quake in one piece, many could not help but notice the sky.

"Mike, look at all those stars," a voice chimed in out of the shadows. The dry desert air was transparent, and with most of Los Angeles and Ventura deprived of electricity, our urban skies were light pollution-free for the first time since God-only-knows-when. I looked up into a sky ablaze with stars I'd never seen from the astronomy club's remote deep-sky observing site, let alone from my backyard.

Along the western horizon was Orion the Hunter, retiring after a night of travails, defeating both enemy and beast alike. As the mighty Hunter sank in the west, he seemed to be dragging the entire winter Milky Way with him. Farther to the east were Gemini and Cancer, under which nestled the head of Hydra the Sea Serpent. Hydra snaked beneath Leo and Virgo, with Corvus the Crow and Crater the Cup sitting on its back. High in the east was the Realm of the Galaxies, that conglomeration of galaxies stretching from Canes Venatici to Virgo. Before astronomers deduced their true nature, these island universes were once coined "spiral nebulae."

Winter's brilliant stars were falling to the west horizon, while the less-conspicuous, but nonetheless welcome, stars of spring mounted the eastern sky. Under this starry dome, my neighbors turned away from the shock of their loss, if only for a few moments, to appreciate the splendor of the night sky without light pollution, some for the first time.

Suddenly a tiny grain of interplanetary dust traveling a dozen or so miles a second plowed through the Earth's upper atmosphere, high above our heads. "Wow, a meteor!" said everyone who happened to be facing the right direction. It was so bright that people with their backs to the bolide turned around, wondering what was causing the flash in the sky. After that, most of us kept an eye heavenward lest another shooting star sneak by unwitnessed.

"Hey, Mike, there's a star moving up there," said a kid whose voice I recognized as coming from the local street hockey fanatic, living a few doors down.

"Where is it?" I replied, moving over to his extended arm. I recognized the "star" immediately as a satellite. Since it was traveling north to south, it must have been a military satellite, since most civilian ones go east or west. But this was a faint artificial moon and probably wouldn't have been seen by any of us if the Southern California megapolis had its normal complement of electrical energy.

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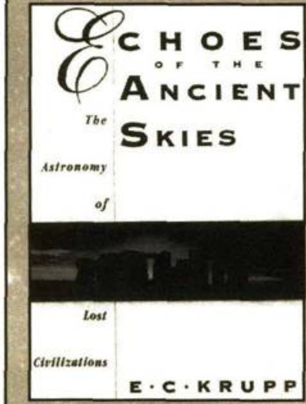
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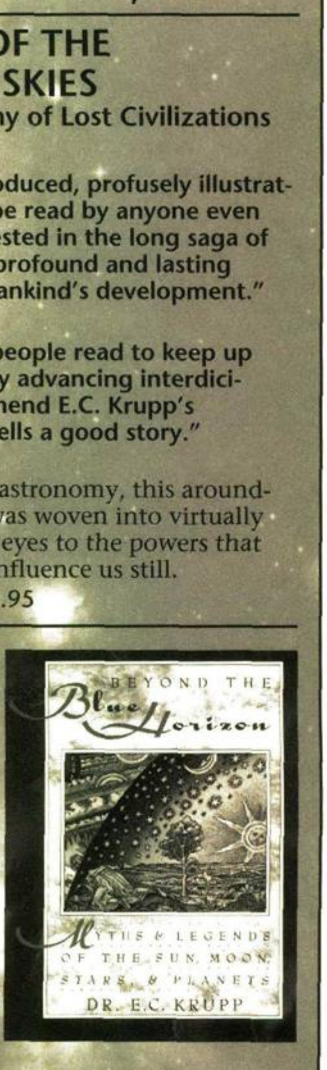

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And so began an impromptu, post-quake star party. I introduced everybody to Leo and its neighbors, using my flashlight as a pointer. After first locating the Big Dipper's pointer stars, I helped people discover the North Star for the first time. Everyone was treated to a naked-eye star cluster: the Beehive in Cancer. After everyone spotted Sirius I mentioned its distance from Earth, which led to an explanation of a light-year. To many, it was astonishing that we were seeing the stars as they were many years ago. Most of my neighbors latched onto the notion that in a literal sense astronomers were time travelers.

With that, I stretched their awareness out 2.5 million light-years to the Andromeda Galaxy, whose light started its journey to our eyes when humans first appeared on Earth. Low in the northwest lay the galaxy. Gasps of amazement resonated through the crowd as, one by one, people found the galaxy without any optical aid. "Totally awesome!" said the street hockey kid.

And so it went.

Soon neighbor was helping neighbor find constellations and fuzzy patches of light I was pointing out, paying more attention to the heavens than to the minor aftershocks that buffeted so-called terra firma.

At one point I even considered attempting an astrophoto or two, but the quake's aftershocks, and the common-sense rule that quake-damaged buildings should be avoided, kept me from running into the house to retrieve some equipment. Besides, as the thought occurred to me, twilight was starting to break over the mountains to the east.

As dawn's first light crept across the sky, we wrapped up our communal sky tour and, with increasing twilight, headed inside to assess the property damage, clean up, and get on with our lives.

What happened that Monday morning was awesome and terrible. Many people in Southern California lost their possessions, homes, and even their lives. Still, a ray of good came out of the tragedy, at least in my neck of the woods. In the still, warm predawn morning, wonders of the night sky visited our neighborhood, giving some their first clear view of the cosmos. We learned that astronomy was for everybody, not just for the scientifically elite. If anything, the experience made us appreciate what we were giving up to urban light pollution.

And who knows? Perhaps some of my neighbors were moved to take their first tentative steps, after a shaky start, into a lifelong enjoyment of astronomy. □

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8"	95.00	8"	85.00
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11"	119.00	11"	109.00
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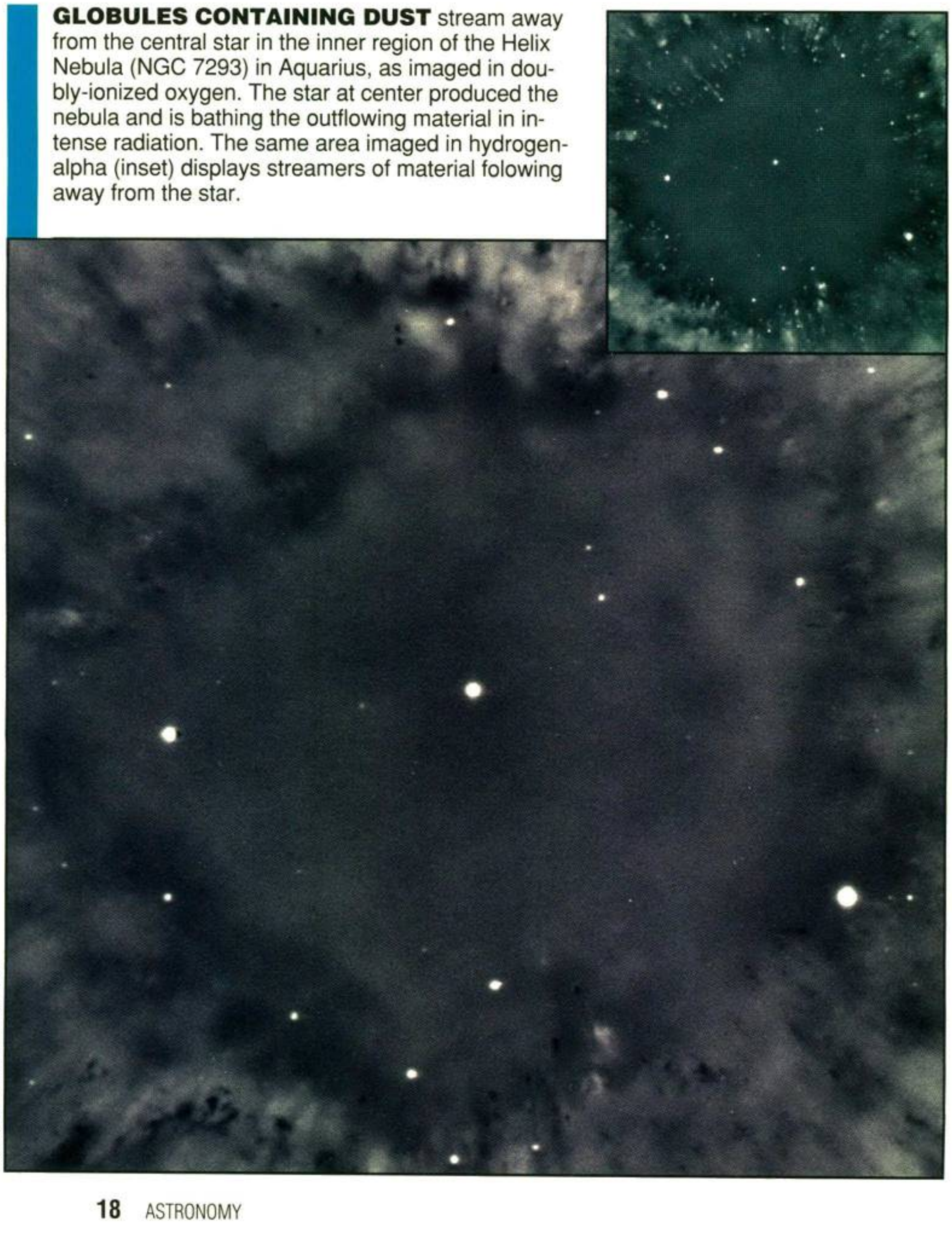
ASTRONEWS

Inside the Helix Nebula

What is life like inside a planetary nebula, the shell of gas expanding away from a dying star? Astronomers Jeremy R. Walsh and John Meaburn used the 3.6-meter New Technology Telescope at La Silla, Chile, to probe the nearest planetary, the Helix Nebula in Aquarius (NGC 7293). The Helix lies a mere 425 light-years away and covers half the Moon's diameter in the sky, so it offers astronomers the best chance to resolve small nebular details. Walsh, an astronomer at the European Southern Observatory, and Meaburn, of the University of Manchester, found some surprises waiting in their deep images of the nebula's central region.

The images reveal numerous small knots, tails, and globules apparently speeding away from the central star. In hydrogen-alpha light the knots have luminous tails pointing away from the central star, suggesting the star's intense radiation is spreading the knots outward. In the light of doubly ionized oxygen many of these knots appear as dark globules backlit by glowing gas behind them, suggesting they contain copious amounts of dust.

Walsh and Meaburn suggest that either the star cast off numerous globules during one of its phases of mass loss or they may have formed when the star's fast, hot wind collided with the earlier, slower wind. Further observations of the globules should reveal the amounts of gas and dust they contain, which should suggest their origin more clearly.



GLOBULES CONTAINING DUST stream away from the central star in the inner region of the Helix Nebula (NGC 7293) in Aquarius, as imaged in doubly-ionized oxygen. The star at center produced the nebula and is bathing the outflowing material in intense radiation. The same area imaged in hydrogen-alpha (inset) displays streamers of material folowing away from the star.

Jeremy R. Walsh, ST-ECF, ESO

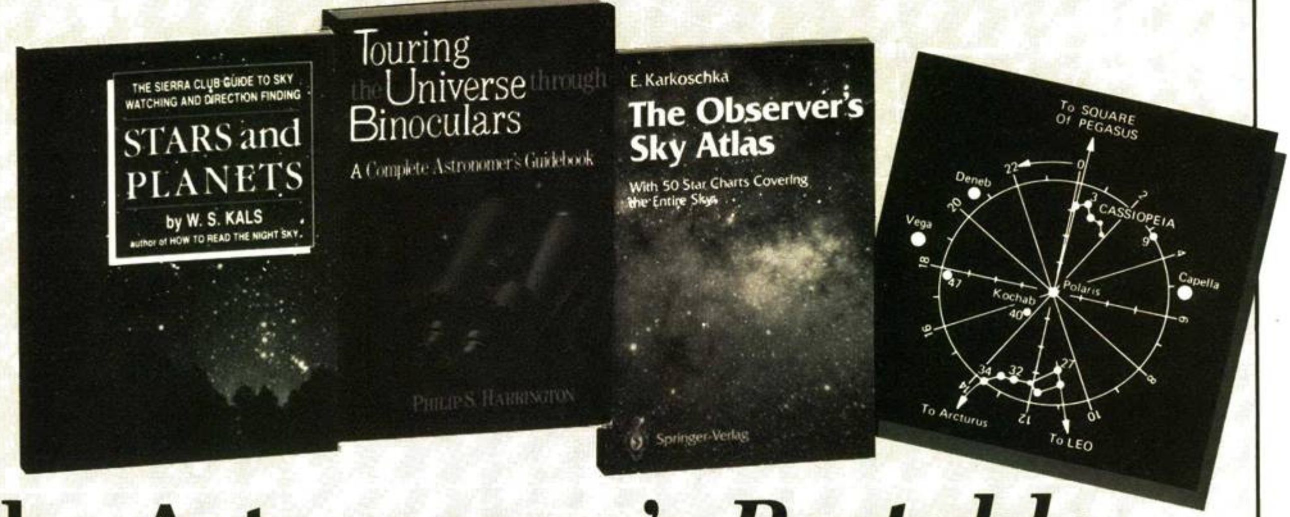
Novel Approach Suggests Universe is Open

Physicist Ruth Daly of Princeton University has developed a new way to calculate the expansion rate of the universe, and her preliminary findings suggest the cosmos will expand forever without collapsing back on itself.

Daly studied the polar lobes of 10 distant radio galaxies, examining how their spectra change with distance from the galaxies' centers. High-speed electrons shot from the galaxies' nuclei gradually lose energy as they move outward and give off less radio energy. Daly used the progressive dimming of these electrons to calculate a physical size for the galaxies' lobes independent of their distance from us.

Next, Daly compared her calculations with physical size estimates based on the galaxies' angular sizes and measured distances. This relationship, according to Daly, indicates how the rate of expansion of the universe has changed over time. This rate of expansion can be measured locally, but distant sources such as Daly's radio galaxies are necessary to infer how the expansion rate has changed as the universe evolved.

The results suggest the universe contains only about 1/10th the mass needed to eventually halt its expansion and create a "Big Crunch." Says Daly, "It looks like the universe is a one-time occurrence and will not collapse back on itself and reform." She cautions,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©Newbridge Communications, Inc. Astronomy 6/94 however, that her findings are preliminary and that observations of 100 or more such radio galaxies will be needed before she will feel certain about her results.

Screams from a Distant Star

Until this year astronomers believed NGC 1097 in Fornax was a run-of-the-mill spiral galaxy. Now a research team has discovered what appears to be a supermassive black hole in the galaxy's core and has devised a method for detecting black holes in other galaxies. The research was carried out by Mike Eracleous and Mario Livio of the Space Telescope Science Institute, Jules Halpern of Columbia University, and Thaisa Storchi-Bergmann of the Universidade Federal Rio Grande do Sul in Brazil.

Most theorists believe so-called active galaxies like NGC 1097 have circular accretion disks around the central black holes. As the black holes swallow stars and gas, the accretion disks heat up and radiate energy. Astronomers can infer the existence of an accretion disk from the presence of emission lines in a galaxy's spectrum. Because part of an accretion disk appears to move away from Earth and part toward it, the galaxy's emission lines appear doubled, and the character of the doubling reveals the shape of the accretion disk.

Eracleous and his colleagues discovered double emission lines in NGC 1097 that did not exist in 1985, when the galaxy was last observed in detail. The astronomers propose that a star fell into the accretion disk of NGC 1097 and was stripped apart, releasing a burst of energy that strengthened the previously unseen lines. Moreover, they studied the properties of the emission lines and suggest that NGC 1097 has an elliptical, rather than a circular, accretion disk. The astronomers know of at least 17 more active galaxies with double emission lines and believe that studying them may strengthen the case for the existence of previously unknown elliptical accretion disks and supermassive black holes.

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DOES A BLACK HOLE LURK INSIDE NGC 1097? Recently discovered double emission lines in the galaxy's spectrum may be best explained by the existence of a supermassive black hole.

Galaxy Cluster Favors Hot Dark Matter

Astronomers at the Cerro Tololo Inter-American and European Southern Observatories in Chile have detected the brightest members of a galaxy cluster located some 13 billion light-years away in the constellation Sculptor. A galaxy cluster existing at this distance is forcing astronomers to rethink some ideas about the nature of dark matter, stuff in the universe that does not interact with light and is therefore invisible.

Theories that explain the formation of galaxy clusters assume the universe contains two forms of dark matter: cold and hot. If dark matter is cold, clusters would have taken a long time to assemble, coalescing at a time much later than the Big Bang. If dark matter is hot, clusters would have formed shortly after the Big Bang, and astronomers should be detecting them at greater distances.

Though the Sculptor cluster's immense distance does not seem to favor the existence of hot dark matter, the theory that allows for that type of matter fails to explain certain aspects of galalxy formation. Theorists are currently investigating model universes where both types of dark matter can exist.

STScI

A DISTANT GALAXY CLUSTER some 13 billion light-years away adds credence to the existence of hot dark matter in the universe.

Earth in Line for Time Tune-up

The International Earth Rotation Service has announced that an extra second will be added to the month of June. A leap second, first introduced in 1972, can be applied twice a year to keep universal time (UT) synchronized with international atomic time (IAT). IAT is based upon vibrational frequencies found in atoms and molecules employed by various atomic clocks around the world.

Atomic clocks have an accuracy of around one part in a billion, while UT, based upon the daily motion of stars over Greenwich, England, lacks comparable accuracy due to variations in Earth's rotation.

Pull up a chair and tune into the event by listening to U.S. National Bureau of Standards time signal station WWV, located at 2.5, 5, 10, 15, and 20 MHz on your shortwave radio. Canadian listeners can tune into CHU Canada at 3.330, 7.335, and 14.670 MHz.

Festivities commence at one second to midnight (UT) June 30; that's 7:59:59 p.m. EDT. No radio, you say? Call the U.S. Naval Observatory master clock at (202) 653-1800.

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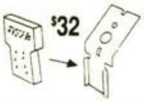

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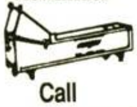

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NASA Issues Mars Recovery Plan

Two spacecraft are slated to fly replacement missions for the failed Mars Observer mission, which fell silent two days before entering Martian orbit on August 21, 1993. Launched in 1996 and 1998, the Mars Surveyor spacecraft will conduct photographic and remote-sensing surveys Mars Observer was to accomplish. The decision to fly new missions came after NASA fully digested the findings of a board designated to investigate Mars Observer's failure.

The board's findings suggest that oxidizer might have leaked through check valves and accumulated in fuel lines during the craft's 11-month cruise. When controllers were readying its propulsion system for entry into Martian orbit, oxidizer came into contact with fuel, which led to an explosion that either destroyed vital spacecraft systems or sent the craft into a tumble from which it could not recover. After the accident NASA considered flying a second Mars Observer spacecraft built from leftover hardware. However, given the board's findings the agency thought it prudent to build a replacement mission from scratch.

NASA has earmarked $77 million in its 1995 fiscal budget to construct the first Surveyor spacecraft. Instruments similar to those on Mars Observer will fly on this craft. The second Surveyor, launched in 1998, will carry the balance.

In a separate initiative, a Mars Environmental Survey lander will be launched in 1996 to test a new generation of Mars lander technology. The second Surveyor spacecraft will provide radio relay services for a lander, based on a MESUR design, to be launched in 1998.

Aside from the short-term goal of making up for the loss of Mars Observer, the

AMATEUR NEWS

Explore the Universe in Flagstaff

ASTRONOMY: Alan Dyer

UNIVERSE 94, like Universe 93 held in San Diego, will feature a large exhibit hall showing the latest in hobby merchandise.

The latest in equipment, presentations by amateur astronomers, discussions lead by professional astronomers — UNIVERSE 94 will have it all. This jam-packed national astronomy fair takes place Saturday and Sunday, June 25 and 26, at the University Union on the campus of Northern Arizona University in Flagstaff. Dozens of manufacturers — some with special show bargains — will display books and atlases, telescopes, accessories, and astronomy software.

Come to hear Sallie Baliunas, Clark Chapman, Kathy DeGioia Eastwood, Alan Dressler, Dave Eicher, Eleanor Helin, David Levy, Jack Newton, Claude Nicollier, John Percy, Caty Pilachowski, Seth Shostak, Alan Stern, Virginia Trimble, Jean Turner, Mike Zeilik, and many others discuss comets, stars, galaxies, the universe, and techniques for observing them. Attend a star party on Saturday evening. On Monday, you can tour the U. S. Geological Survey, the U. S. Naval Observatory, and the Anderson Mesa station of Lowell Observatory, and listen to a public lecture by Carl Sagan. Co-sponsors of UNIVERSE 94 are ASTRONOMY magazine and the Astronomical Society of the Pacific.

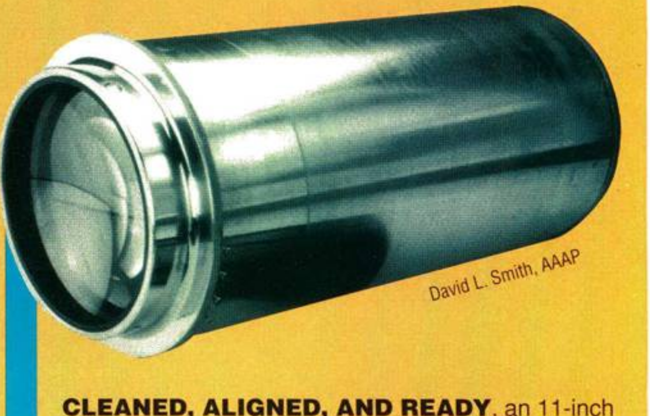
For information about the meeting and a registration packet, contact UNIVERSE 94, ASP, 390 Ashton Avenue, San Francisco, CA 94112, (415) 337-1100, fax (415) 337-5205.

Amateurs Restore Carnegie's Scope

Members of the Amateur Astronomers Association of Pittsburgh (AAAP) are restoring a telescope built over 85 years ago for steel magnate Andrew Carnegie so he could view the 1910 apparition of Comet Halley. Carnegie and Pennsylvania Railroad Company tycoon William Thaw purchased the 11-inch refractor, made by noted optician John Brashear, in 1908 for $5,715 (about $100,000 in today's dollars). The telescope was housed on the campus of the Carnegie Institute of Technology until 1914, when its building was torn down to make way for a new fine arts building. Stored until March 1992, the refractor was then donated to AAAP.

For club members Robert Schmidt and Wade Barbin, the first order of business has been the careful removal of dirt and grime from the objective lens, which over the years had worked loose from its brass mount. AAAP member Steve Miller, an optician with the Contrave Company, conducted an evaluation of the lens. Coincidentally, Contrave is a corporate successor to the John Brashear Company.

Besides concentrating on cleaning the optics, efforts by the team restoring the telescope have included machining new parts based on original factory drawings, as well as designing and building a new telescope drive. When it is completed, AAAP members plan to house the refractor in its Wagman Observatory. Says Barbin: "We are dreaming of the day when we can look through it, instead of at it."

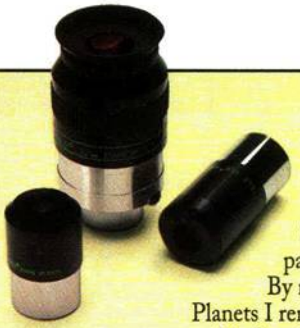


David L. Smith, AAAP

CLEANED, ALIGNED, AND READY, an 11-inch Brashear refractor objective restored by the Amateur Astronomers Association of Pittsburgh awaits first light after being stored for 80 years. AAAP plans to house the refurbished 21-foot-high brass refractor in its Wagman Observatory.

"Not only is Dance useful as an observing session planner, but it's sheer entertainment on some of the historical reconstructions. I recently ran the 'discovery of Pallas by accident in 1802' scenario. it was enjoyable imagining how Olbers felt, when looking for Ceres and chancing to discover Pallas."
Richard T. Coolick,
Bonita Springs, FL

"I have to tell you that I've learned more useful astronomy from your product in a few months than I did in all my time in the classroom. Thank you for enriching my life."
Leslie Kinton,
Guelph, Ontario



"When I was a high-school boy back in the Sixties, I watched Saturn pass behind the Moon. By means of Dance of the Planets I remembered what happened on 8th Oct. 1962! You cannot guess how happy I felt!"
Masahiko Ikeda,
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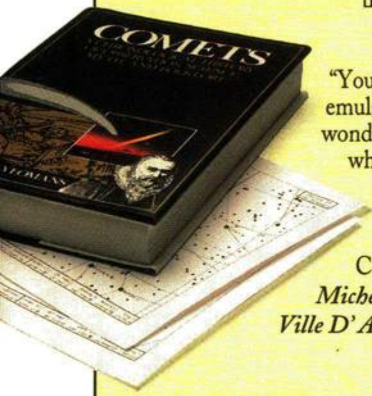
Natural Astronomy.

The Science and Art of Dance of the Planets Through the Eyes of Its Users



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Comet Shoemaker–Levy 9

Watch the July collisions from any angle—see the locations of the Galilean moons and impacts. Run time back to the 1992 breakup. Continue back to see more of its tortured history since its capture by Jupiter decades ago. These are the first known collisions, but many strong comet perturbations and even other temporary captures can be recreated with Dance.

Find S-L 9. Using Dance, Gary Dowdle of San Antonio was able to image S-L 9 in January with a CCD on a 16" telescope!

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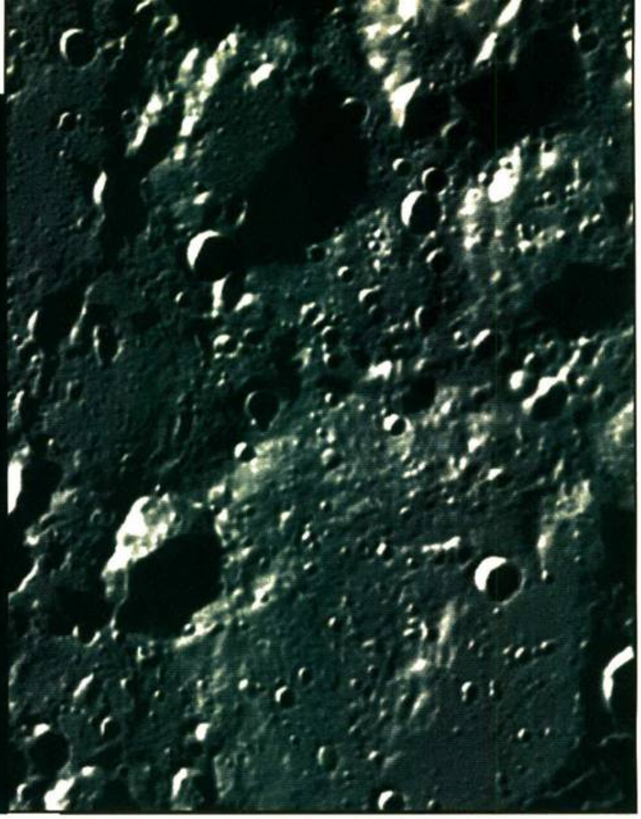
Surveyor program is slated to send orbiters and landers to the Red Planet every 25 months through the early part of the 21st century. After this series of flights, NASA hopes to mount an unmanned mission that would return soil and rock samples to Earth for study.

Clementine Sends its First Lunar Images

The Department of Defense's Clementine probe reached lunar orbit on February 19, 1994, less than a month after its launch. One of the first pictures it took shows the crater Nansen (bottom right in the image), a 75-kilometer-wide crater near the Moon's north pole. Even under favorable observing conditions this crater is nearly invisible from Earth — lying on the lunar limb — but Clementine's pole-to-pole orbit is ideal for mapping such regions.

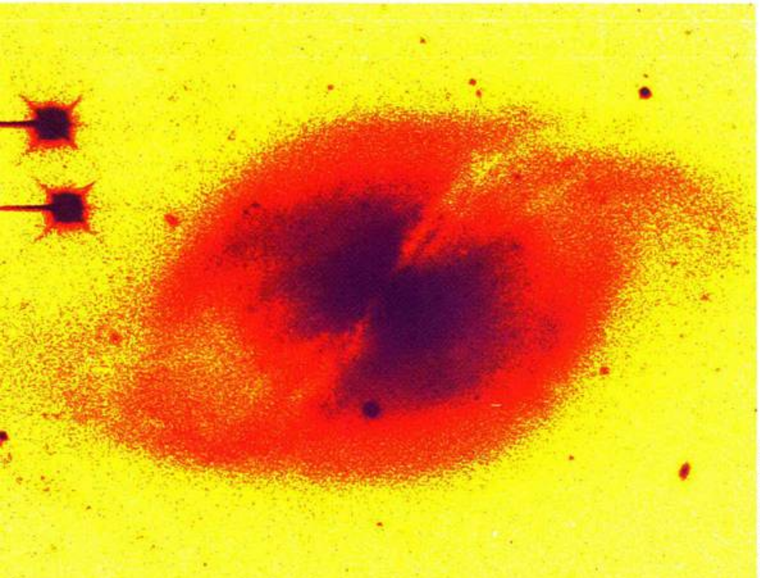


Naval Research Laboratory

Herschel's Double Stars Revisited

An astronomer at the U.S. Naval Observatory has uncovered the true nature of some double stars catalogued by 19th-century observer Sir John Herschel. Using a CCD camera and the UNSO's 40-inch reflector in Flagstaff, Arizona, Richard Walker examined ten double stars Herschel catalogued during an 1834 expedition to South Africa. Herschel discovered nearby nebulae and classified them as components to these star systems. Walker's results have shown that some of these nebulae are not associated with their catalogued double stars but are in fact galaxies or nebulae appearing along the same line of sight.

Walker intended to see if some of the double stars were gravitationally bound to nebulae Herschel referred to as "luminous clouds." In the case of double star HJ 2574, Herschel identified a faint nebular "C" component, which Walker has actually found to be two galaxies colliding millions of light-years away. In other instances, Walker has discovered that some of Herschel's nebulous components are really multiple stars. Aside from determining the true nature of these "nebulae," Walker has also detected component stars to some of Herschel's doubles, stars that were previously unknown.



Richard Walker, USNO

THESE COLLIDING GALAXIES were thought to be double stars by the 19th-century observer Sir John Herschel. He originally classified them as the gaseous "C" component of double star HJ 2574, the 2574th member of a double star catalog he created in 1834 while at the Cape of Good Hope Observatory in South Africa. This CCD image, obtained by U.S. Naval Observatory astronomer Richard Walker, shows Herschel's nebulous "C" component is a pair of colliding galaxies.

NASTEC is back — and bigger than before

A consortium of small telescope operators started in 1992 with 13 college and university members, each with telescopes 16 to 40 inches in diameter (see AstroNews, June 1993). Now 25 members pool their observations, using scopes up to 75 inches across. The emphasis remains on multiwavelength observations and establishing connections between large and small astronomy programs. For more information

First Asteroid Moon Found

Galileo, NASA's space probe en route to Jupiter, has discovered what is probably the first known satellite of an asteroid. The probe sped past the asteroid Ida on August 28, 1993, and the slow process of downloading images and data from the craft's near-infrared mapping spectrometer has continued for months.

On March 3, 1994, Galileo Project Scientist Torrence Johnson announced the discovery of a "blip" consisting of more than a few pixels visible in data from both the solid-state imaging system and the spectrometer.

Based on the simultaneous observation, the scientists believe a natural "moon" orbits Ida — the first satellite of an asteroid to be discovered. NASA scientists expect to release an image soon. See the July issue of ASTRONOMY.

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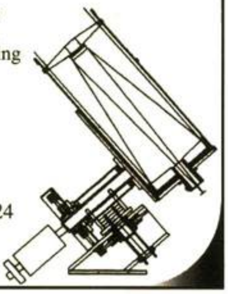

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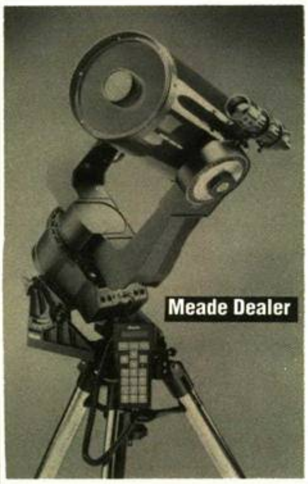

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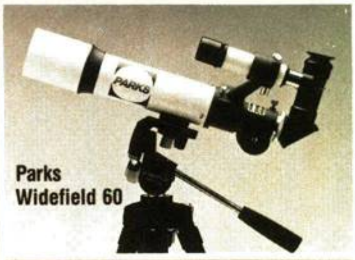

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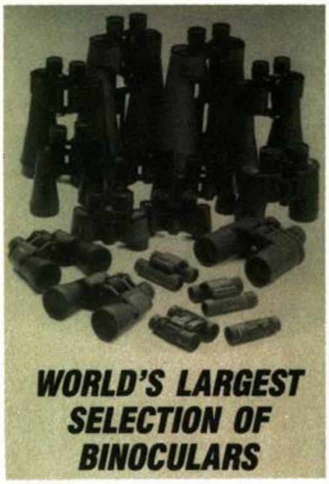

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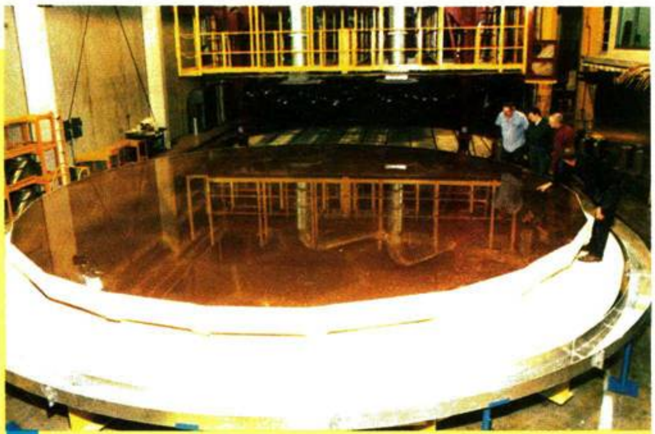
Gemini II Starts



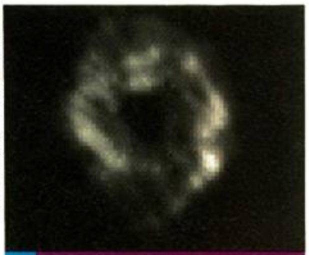
THE MIRRORS FOR GEMINI I AND II will resemble that for Japan's Subaru telescope (seen above). Corning first fuses glass hexagons together to form a large blank. To get the desired concave shape, they then reheat the mirror in an oven over a shaped mold.

A debate has raged about the Gemini project's decision to use an 8.1-meter meniscus mirror (one with a uniform thickness that follows the curvature of the concave mirror). Some astronomers voiced concern about the stability of such a mirror and the ability of a mirror mount to properly support a large thin mirror. Recently, a review committee has concluded that the mirror and the mirror-mount design will meet the telescope's goals. With the committee's confident report, the project has contracted with Corning to produce the mirror for the second Gemini telescope. Corning will finish the mirror for Gemini in 1995 and that for Gemini II in 1996. (See "Big Scopes," August 1994, for more information on these scopes.)

What's Next — Old Lace?

Astronomers recently announced the discovery of tin in the space between stars and described how stars eject the lowly metal (see AstroNews, February 1994). Now a team of astronomers led by Jason Cardelli of the University of Wisconsin has used the Goddard High Resolution Spectrograph aboard Hubble Space Telescope to find other elements contained in interstellar space. The researchers discovered arsenic and selenium and set upper limits for the amounts of tellurium and lead.

Six heavy elements are now known to exist in space — arsenic, gallium, germanium, krypton, selenium, and tin. Besides expanding our knowledge of which elements exist in dust grains in interstellar space, the team's observations provide insights into the mechanisms that create new elements in dying stars. Stars synthesize elements up through those in the iron group (iron, nickel, and chromium) from lighter ones. The light elements capture protons and neutrons to build heavier nuclei. But elements heavier than iron can't form this way. They require the capture of a single neutron and its subsequent decay into a proton to slowly build up each atom's nucleus. Further study of heavy elements in interstellar dust will help astronomers understand how stars create atoms and enrich space with them.



Chris Impey, Univ. of Arizona

LOOKING LIKE A GIANT EYE, this radio image of diffuse galaxy UGC 6614 was taken with the Very Large Array in Socorro, New Mexico. The galaxy lies about 210 million light-years away and, at 250,000 light years across, is much larger than the Milky Way. The total mass of UGC 6614 is thought to be 20 billion times that of the Sun.

A New Class of Variables?

Whitish stars such as Gamma Doradus aren't supposed to change slowly in brightness. The general wisdom in astronomy suggests that these stars should vary quickly, over tens of minutes, because their outer layers pulsate in and out. Yet Kevin Krisciunas of the Joint Astronomy Center in Hilo, Hawaii, has found 12 stars, including Gamma Doradus, that do the seemingly impossible — they vary slowly, over a period of hours to days.

Krisciunas has eliminated the possibilities that the stars exist in eclipsing binary systems or have strong magnetic fields that create bright or dark regions responsible for the variations. He proposes that the stars do pulsate, but non-radially. The pulsations go around the star instead of in and out. Roger Griffin of the Observatories in Cambridge, England, took spectra of one of the stars, 9 Aurigae. The shapes of the spectral lines change, just what one would expect if the star pulsates non-radially. Astronomers need more observations of the other 11 stars to decide whether Krisciunas' non-radial pulsation theory is correct and to determine if the stars form a new class of variable star.

New Capability for Very Large Array

Until recently the Very Large Array radio telescope, operated by the National Radio Astronomy Observatory and located outside of Socorro, New Mexico, could receive signals at frequencies only as high as 23 gigahertz. A $1 million grant by the Mexican government to Luis Rodriguez of the National Autonomous University of Mexico has made possible the development of ten new receivers at frequencies from 40 to 50 GHz. With the new high-frequency capability, astronomers will look at galaxies, molecular clouds in our Milky Way Galaxy, shells of gas around stars, and disks around stars where planets may be forming.

To take advantage of the new receivers, Michael Kesteven of the Australian Telescope National Facility mapped the high and low spots of all 28 antennas and picked out the 10 with the smoothest surfaces. These 10 best antennas will use the new high-frequency receivers. Kesteven also adjusted the 172 aluminum panels of one antenna and nearly doubled its high-frequency performance. VLA engineers plan to use Kesteven's technique to readjust all of the antennas in the future. Kesteven says, "We're pushing the VLA way beyond what the antennas were originally designed to do." ☐

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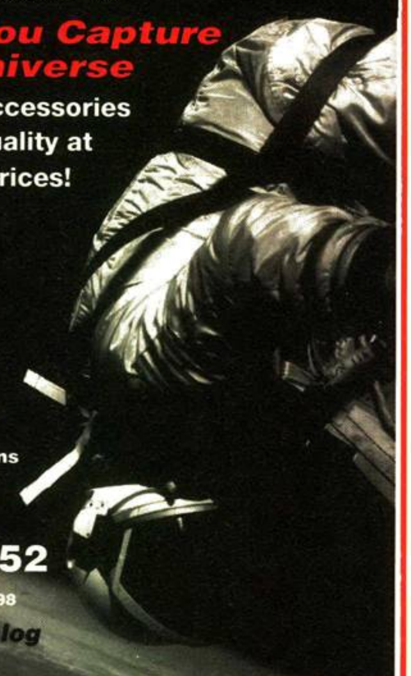

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"Dear Mr. Christen,

The new STARFIRE EDT arrived a few days ago. It was a joy to unpack it and to set it up: it looks beautiful and bears testimony of exquisite craftsmanship throughout. Yesterday the sky cleared up and the telescope got first light. I was out under the stars for many hours — looking, testing and also comparing the new instrument with other telescopes. Yet I soon realized that there was no reason to use any other instrument: the STARFIRE simply was superior. Deep sky views were sharper, cleaner and more contrasty than I have ever seen. And best of all: with this instrument the problem of spurious color definitely is gone — incredible! Jupiter was quite a show at all magnifications I tried. What amazed me was how bright its disc looked even at high magnification, with the colors in the belt system readily visible. There was a wealth of detail, much more than I could have drawn: it was a totally satisfying night of observing. Thanks for a superb instrument."

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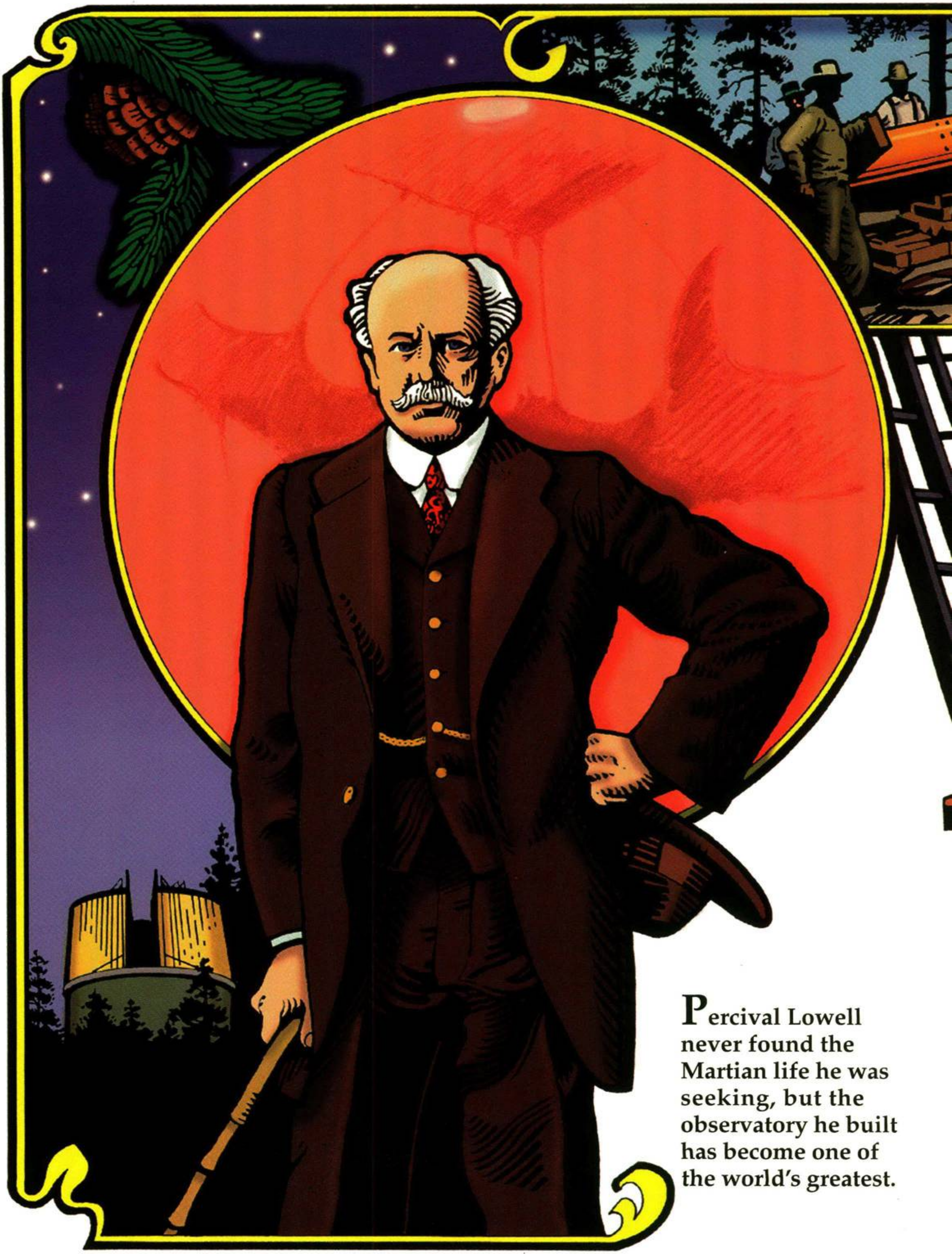
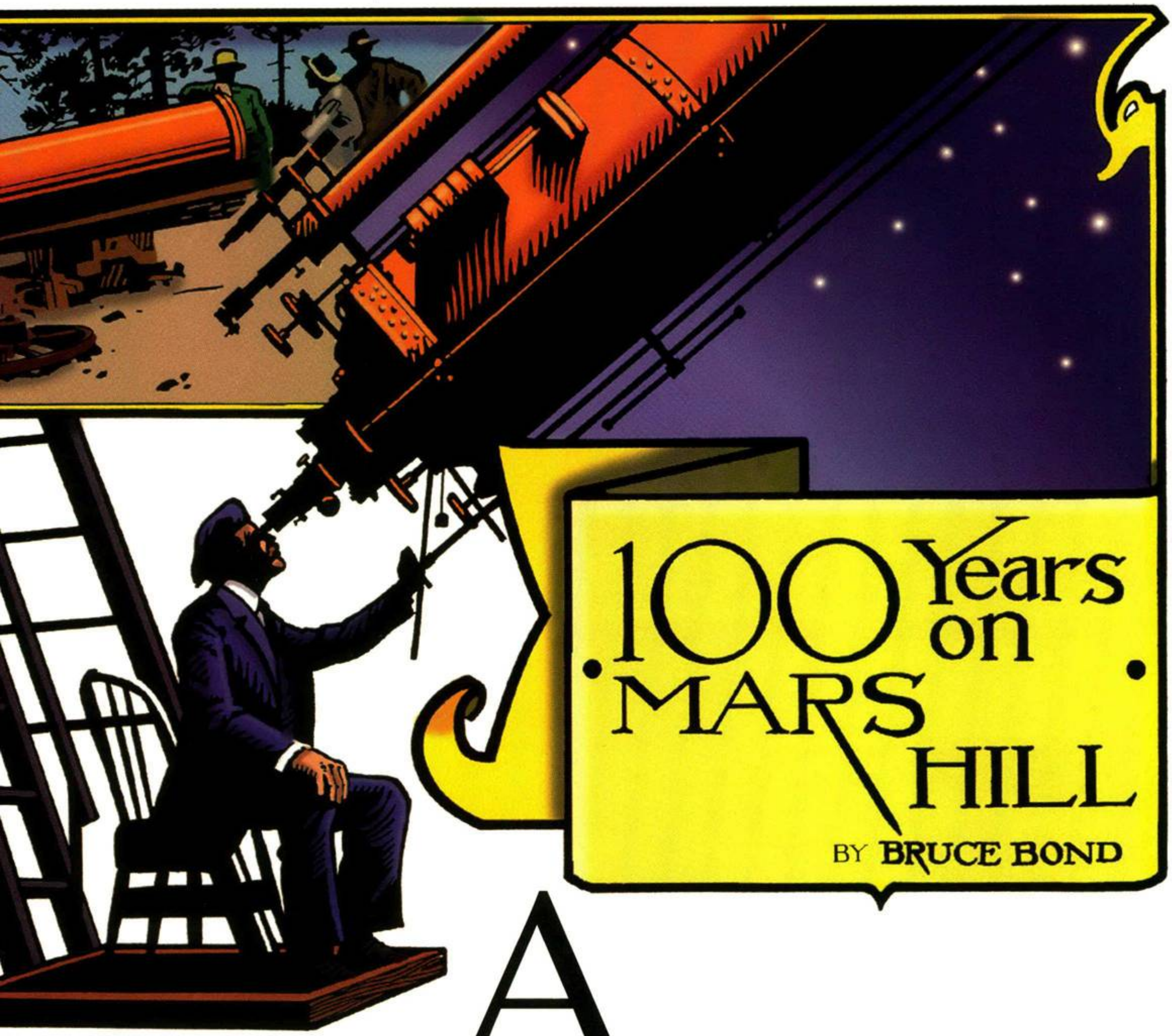


Percival Lowell never found the Martian life he was seeking, but the observatory he built has become one of the world's greatest.

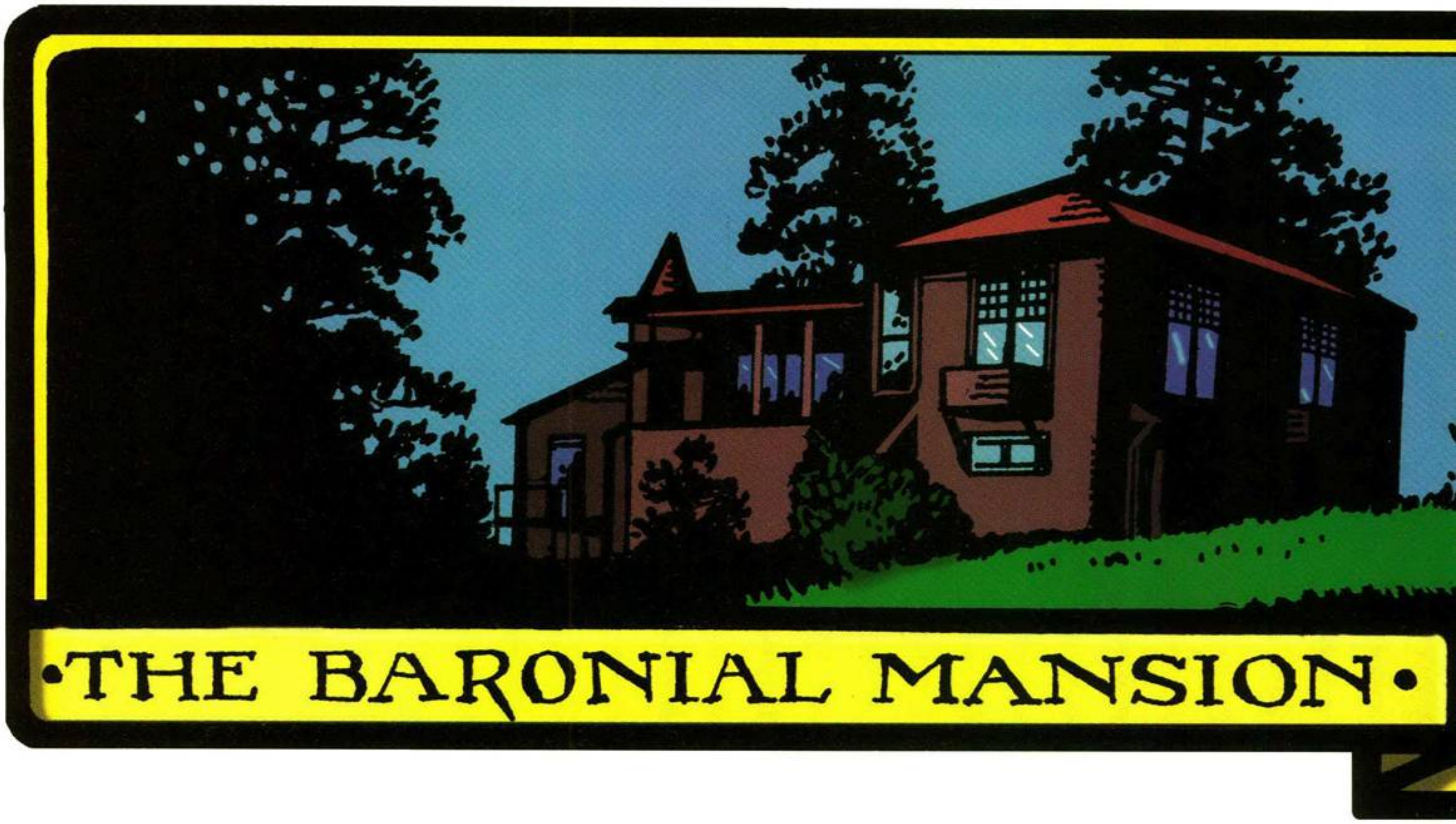


100 Years on MARS HILL

BY **BRUCE BOND**

A century ago, one man put his heart into an obsession and set mankind on the path to the planets and the universe. Lowell Observatory was the brainchild of a wealthy Bostonian who was pursuing an idea that most astronomers, then and since, have heartily disparaged — searching for life on Mars.

But if Lowell failed to find his Martians, the observatory he created made great discoveries nonetheless: the planet Pluto, many asteroids and comets, and the key to measuring the expansion of the universe. These discoveries took Lowell's observatory out of the realm of a rich man's hobby and set it on its present course as one of the world's greatest astronomical laboratories.



·THE BARONIAL MANSION·

Percival Lowell was born on March 13, 1855, into wealth and privilege. His father instilled in him the idea that every self-respecting man must work at something significant. Like his contemporary, George Ellery Hale, the builder of the 200-inch telescope on Palomar Mountain, Lowell was a fine scholar with a gift for mathematics. As a boy, he developed a love of astronomy and made his first planetary observations with a $2^{1}/_{4}$-inch refractor from the roof of the family house in Brookline, Massachusetts.

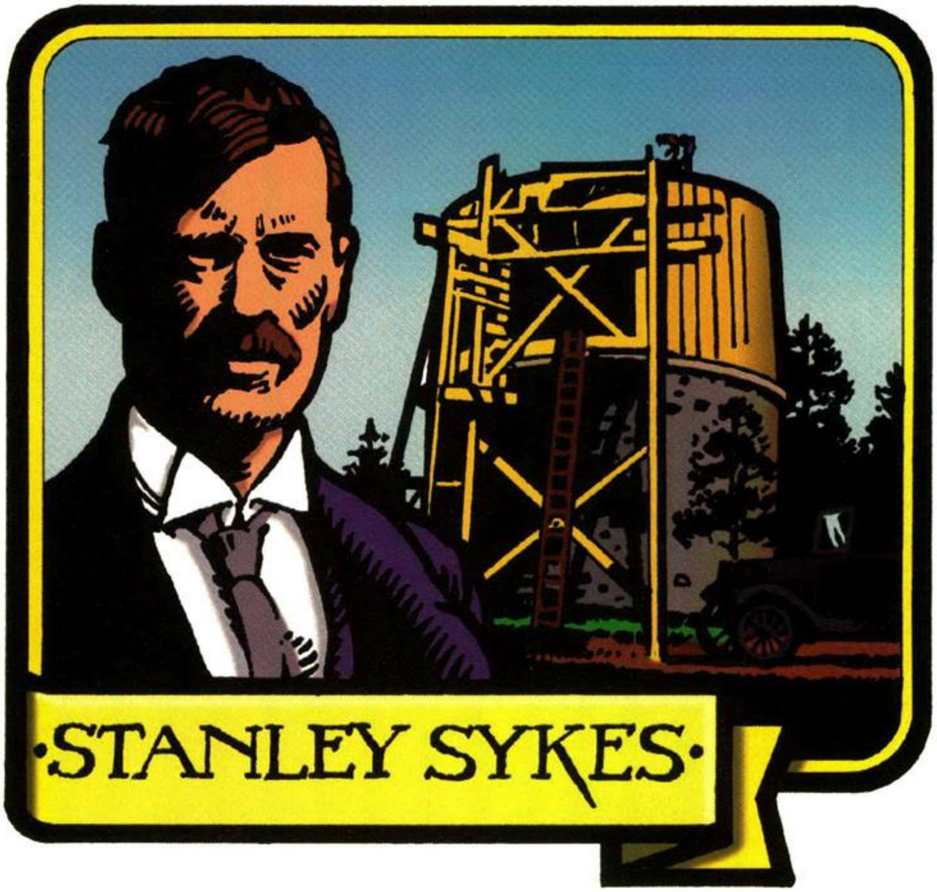
Lowell graduated Phi Beta Kappa from Harvard College, where he studied mathematics, physics, the classics, and history. Professor Benjamin Peirce, the great mathematician, spoke of him as one of the most brilliant scholars he had ever seen. Lowell traveled extensively, both before and after graduation, first building up a fortune with the family linen mills, then spending a decade in the Orient, and eventually serving as general counsel to the first Korean embassy to the United States. As he reached his forties Lowell looked set for a career as a statesman.

Then he threw it aside. To this day no one knows why Lowell suddenly abandoned his diplomatic career to return full-time to his old passion for astronomy. Lowell left no written clue, but the decision may have been sparked by reports from the Italian astronomer Giovanni Schiaparelli of linear *canali* on the surface of Mars.

Canali translates into channels, not canals (which would imply intelligent life), but Lowell's imagination was fired all the same. Poring over Schiaparelli's observations, Lowell conceived an elaborate hypothesis in which a dying civilization of Martians was fighting nature on their desert planet. The canals were to carry water from the polar caps to their cities, he supposed, and the "oases" where canals joined were pumping stations.

They may have all been a matter of mistranslation, but Schiaparelli's *canali* set a powerful force in action nonetheless. Schiaparelli was suffering from failing eyesight and had to stop his Mars studies; Lowell resolved to pick up where Schiaparelli left off and carry out a close examination of the Martian surface. But to do this he needed a site from which to observe and a powerful telescope.

William Pickering of Harvard Observatory suggested Arizona, then a territory, as the most promising spot. In March 1894, Lowell sent off his 6-inch Clark refractor with another Harvard astronomer, Andrew Douglass, to make tests of nighttime seeing throughout Arizona. ("Seeing" is the term astronomers use to describe how settled the atmosphere is; steady seeing is essential for clear, high-power views.) Soon Douglass had



picked a small logging town high on the Colorado plateau.

Picking Up the Torch

Flagstaff lies at 7,200 feet above sea level and has steady seeing. To test the site thoroughly, Pickering supervised the construction of a temporary dome and arranged with John Brashear, the Philadelphia telescope and instrument maker, for the loan of 12-inch and 18-inch refractors. Six weeks after the groundbreaking in April 1894, Lowell arrived and began regular observations.

These confirmed for him his theory about the Red Planet's habitability and convinced him that a permanent observatory at Flagstaff was worthwhile. Lowell then ordered a 24-inch refractor from Alvan G. Clark, the famed telescope maker in Cambridge, Massachusetts. In the meantime, Flagstaff seeing was so steady that Lowell began systematic observations of Venus and Mercury.

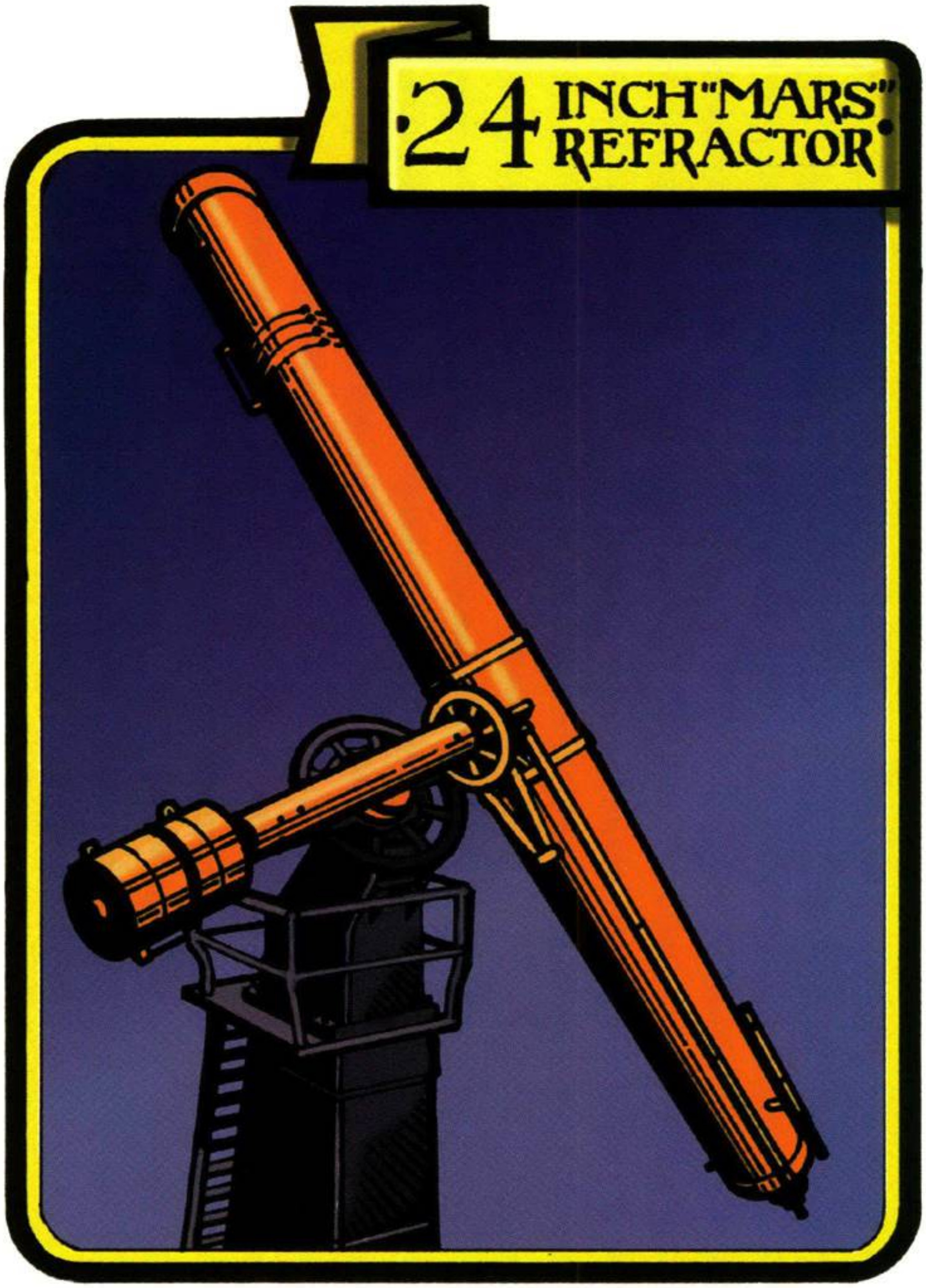
However, trouble soon loomed. As the year wound to a close and winter set in, the weather and observing turned terrible. The weather was so bad that one day Douglass snowshoed to the observatory and had to enter the dome through the shutter. Handyman (and later instrument maker) Stanley Sykes developed his own scale of seeing: "10 is when you can see the Moon, 5 is when you can see the telescope, and 1 is when you can only feel the telescope!"

By March, a discouraged Lowell was ready to give up. He ordered the dome, mounting, and telescope dismantled and relocated to Tacubaya, Mexico, near Mexico City. By the middle of April 1895, the observatory in Flagstaff was closed and empty. But Tacubaya didn't work out either, so Lowell continued to search for an ideal site, even checking out locations in the Sahara and the Andes Mountains.

Eventually, he returned to Flagstaff because it had proved, on average, better than every other site he tested. Douglass went back to Flagstaff in 1896 and the brothers Stanley and Godfrey Sykes built a permanent dome on the edge of a thick, ancient lava flow overlooking the town. Lowell named the site Mars Hill. The great 24-inch Clark arrived with its mounting and Alvan G. Clark himself installed the lens on July 22. Lowell began observations immediately. In his opinion these added further confirmation to his theory, which was already sparking vigorous controversy within the astronomical community.

Where Are the Martians?

At the time, a habitable, Earth-like Mars didn't seem impossible. Maps of Mars and the names given to its features reflected a



terrestrial image. If Mars could have ice caps, seas, and lakes, then why *shouldn't* Lowell's hypothesis be true? His observations and calculations led Lowell to believe that while Mars had a thin atmosphere it could still support life. He didn't speculate on what form that life might take, but he never wavered in his belief that Mars was inhabited.

To spread his ideas, Lowell gave lectures and wrote a series of articles for *Popular Astronomy* and *The Atlantic Monthly*. He also penned three books on the subject: *Mars* (1895), and later on, *Mars and its Canals* (1906) and *Mars as the Abode of Life* (1908). Among the general public at least his ideas initially received wide acceptance.

Mars was in the air, so to speak. And Lowell's theories also struck a resonant chord among writers and a handful of engineers and scientists. H. G. Wells published *War of the Worlds* in 1898. The same year Garritt Serviss wrote *Edison's Conquest of Mars*, and in 1912 the first of Edgar Rice Burroughs' Mars books, *Under the Moons of Mars*, appeared. In this same period, physicist Robert Goddard first dreamed of constructing a rocket that could fly to Mars.

The problem was that most astronomers couldn't see the markings that Lowell claimed. Lowell's telescope was perhaps the world's best for planetary observing, and Flagstaff's seeing often surpassed that at other observatories. But the unceasing skepticism and criticism from professional astronomers, plus a strenuous work schedule, finally pushed Lowell into a nervous breakdown. In 1897 he took a four-year sabbatical from the observatory to recover, leaving astronomer T. J. J. See to act as director in his absence. See proved an unhappy choice — his eccentric and tyrannical personality drove most of the assistants from the observatory. In 1901 Lowell returned with restored energy. He threw himself into making observations leading up to the 1903 Mars opposition, the period of its best visibility.

Lowell also hired two new assistants, Vesto M. Slipher and Carl O. Lampland, to work with him. By 1905 Lampland had taken photos of Mars that seemed to show canals. This was important, because all prior observations had been recorded in drawings, naturally open to dispute on the grounds that they were subjective. But here again, Lowell was thwarted. The details in the photos were grainy and did not meet wide professional acceptance. During the Mars opposition of 1907, Lowell sponsored an expedition to South America (where Mars was visible higher in the sky) and spent eight months himself in Flagstaff observing the Red Planet.

By this time, however, the public's interest in Mars was beginning to wane and Lowell, still clinging tenaciously to his theory, felt himself increasingly on the defensive about the subject of Martian life. Planetary scientists now know that Lowell was correct that Mars has icy polar caps, but wrong about their content. They consist mostly of frozen carbon dioxide, not water. And Mariner and Viking spaceprobes have shown that the Martian channels that do exist have no relation to Lowell's "canals." Viking also put an end to the idea of finding life on Mars, since soil samples showed no traces of it.

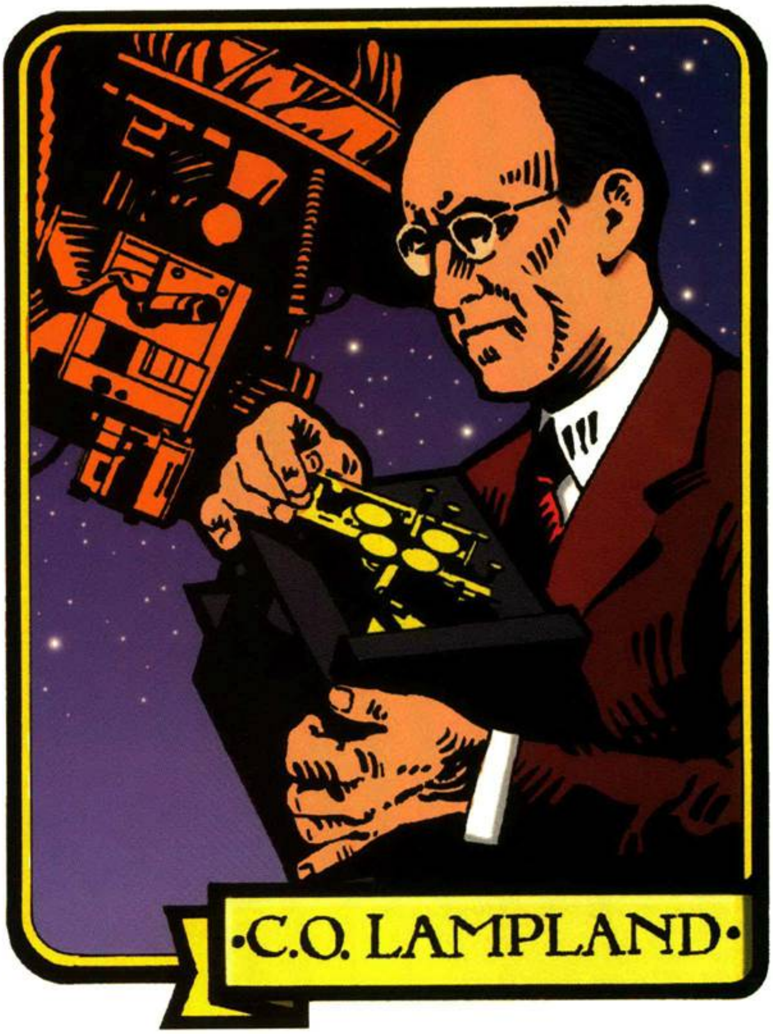
Expanding the Universe

Even though his theories about Martians proved wrong, Lowell's observations laid a foundation of data that was immensely valuable. Nor did he concentrate wholly on Mars; his other planetary observations — of Venus, Mercury, and Saturn — were also useful.

Most productive of all, however, was the work of Slipher, who came to the observatory as a temporary assistant and retired as its director in 1954. Slipher made one of astronomy's most significant discoveries: how to measure the expansion of the universe. Working with the Brashear spectrograph, Slipher began a study of planetary rotation. Then he worked on determining the nature of the "spiral nebulae" — galaxies — whose real nature was unknown at the time.

By 1912, Slipher had obtained spectra of the Andromeda Galaxy (M31) that indicated rotation speeds three times faster than anything then known. More importantly, his examination of a galaxy in Virgo showed that all its spectral lines were displaced toward the red portion of the spectrum. This "redshift" indicated that the nebula was receding from Earth at 620 miles per second, or two million miles per hour. Two years later, Slipher had spectra showing similar shifts for 14 more spirals.

At the 1914 meeting of the American Astronomical Society, Slipher presented the velocities for these spiral nebulae. The trend in the data was clear, but Slipher waited until 1917 to conclude that the enormous speeds of these spiral nebulae indicated that they were "island universes" very distant from our own Galaxy. The results of his studies were soon overtaken by the pioneering work of Edwin Hubble at Mt. Wilson Observatory. Using the greater power of the 100-inch reflector, Hubble proved that the nebulae were indeed distant galaxies like the Milky Way, and he made the first measurements of the universe's rate of expansion.

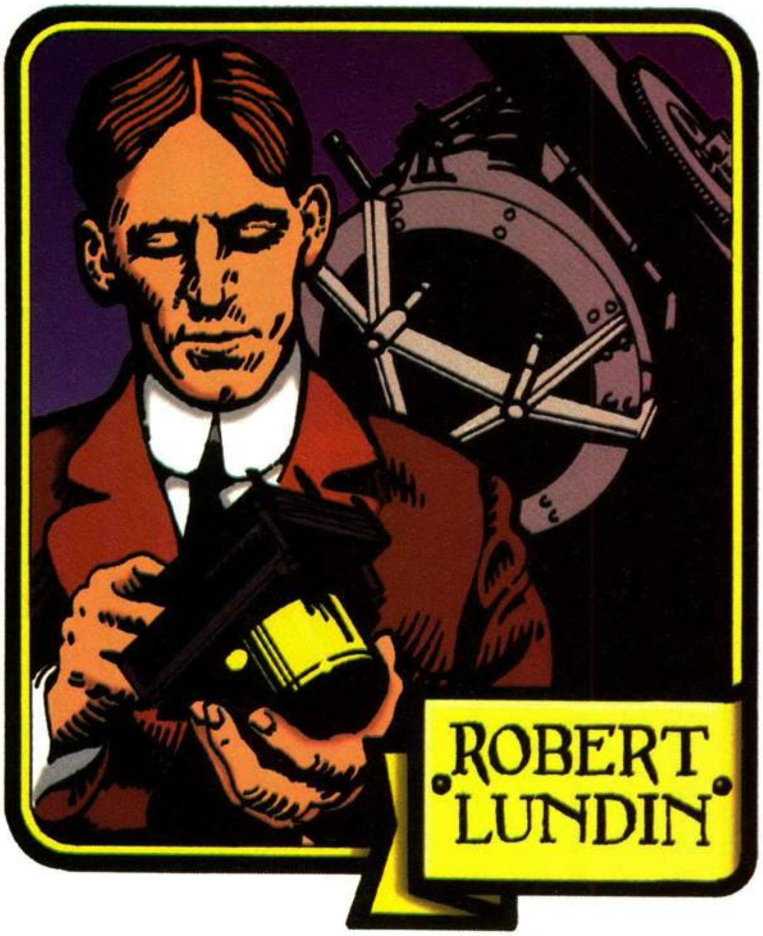


Slipher's discovery, however, had been fundamental to putting astronomers on the right track and his work earned him the Royal Astronomical Society's gold medal and the National Academy of Science's Henry Draper medal.

The Hunt for Planet X

If Mars was the passion that drove the founding of the observatory, the hunt for "Planet X" — a possible planet beyond Neptune — ran a strong second (see "At the Edge of Night: Pluto and Charon," January 1994). As early as 1902, Lowell had proposed that Planet X must exist, a speculation he based on irregularities in the motion of Uranus. Between 1905 and 1915 he conducted two fruitless photographic searches. When Lowell died in 1916, Planet X was still no more than a guess.

In 1928 Clyde Tombaugh, a young amateur astronomer from Kansas, submitted some planet drawings to the staff for a critique. Much to his surprise, he received the offer of a job by return mail. Slipher wanted him to assist in the observatory's third Planet X search. Tombaugh accepted and arrived at the observatory in January 1929.



The instrument he was to use was a gift of A. Lawrence Lowell, Percival Lowell's brother and president of Harvard. He gave the observatory $10,000 to buy a 13-inch refractor lens with a wide field of view built by master optician Robert Lundin of the Alvan Clark firm. With a mounting built largely in the observatory's shop, it was dedicated specifically to the Planet X search.

Tombaugh's job was to set up the telescope and photograph areas of sky where the planet was suspected to be. Each glass photographic plate measured 14" by 17" and contained an average of 300,000 stars. The search method required Tombaugh to take two photographs of a given area approximately a week apart. He would then examine the two plates together in minute detail, inch by inch, on a device called a blink comparator. The machine lets the operator look at the same portion of each plate alternately in rapid succession. Any object that moved between the two exposures stands out clearly because it appears to hop. Tombaugh scrutinized from 30,000 to 60,000 stars per day.

On most plates, he encountered up to 100 moving or changing objects (mostly asteroids and variable stars) that had to be logged, identified, and rejected. On February 18, 1930, Tombaugh blinked the plates taken on January 23 and 29. At 4 o'clock in the afternoon, he found an object that began "popping in and out of the background." The amount it moved told him that it lay in the outer reaches of the solar system — in Planet X territory. He carefully checked a backup plate for confirmation. The object was indeed there. Tombaugh took more photos with the 24-inch to check the object's motion and to compute a preliminary orbit. Planet X had been found.

The observatory announced the discovery on March 13, which was Lowell's birthday and the 149th anniversary of the discovery of Uranus. An 11-year-old girl from Oxford, England, suggested naming the planet Pluto, for the ancient god of the underworld. (Contrary to legend, the name was *not* inspired by the hapless Disney dog that appeared on the silver screen that year — although Tombaugh did say Pluto could have been so named "because it was so doggone hard to find.")

Later, Tombaugh found Pluto on plates taken by Lowell himself. The plates had even been blinked by V. M. Slipher and his astronomer brother Earl during previous searches. The probable reason Pluto had not been found then was that it was a lot fainter than anyone expected. Lowell had thus been successful during his lifetime in photographing Planet X, although he never knew it.

On Beyond Pluto

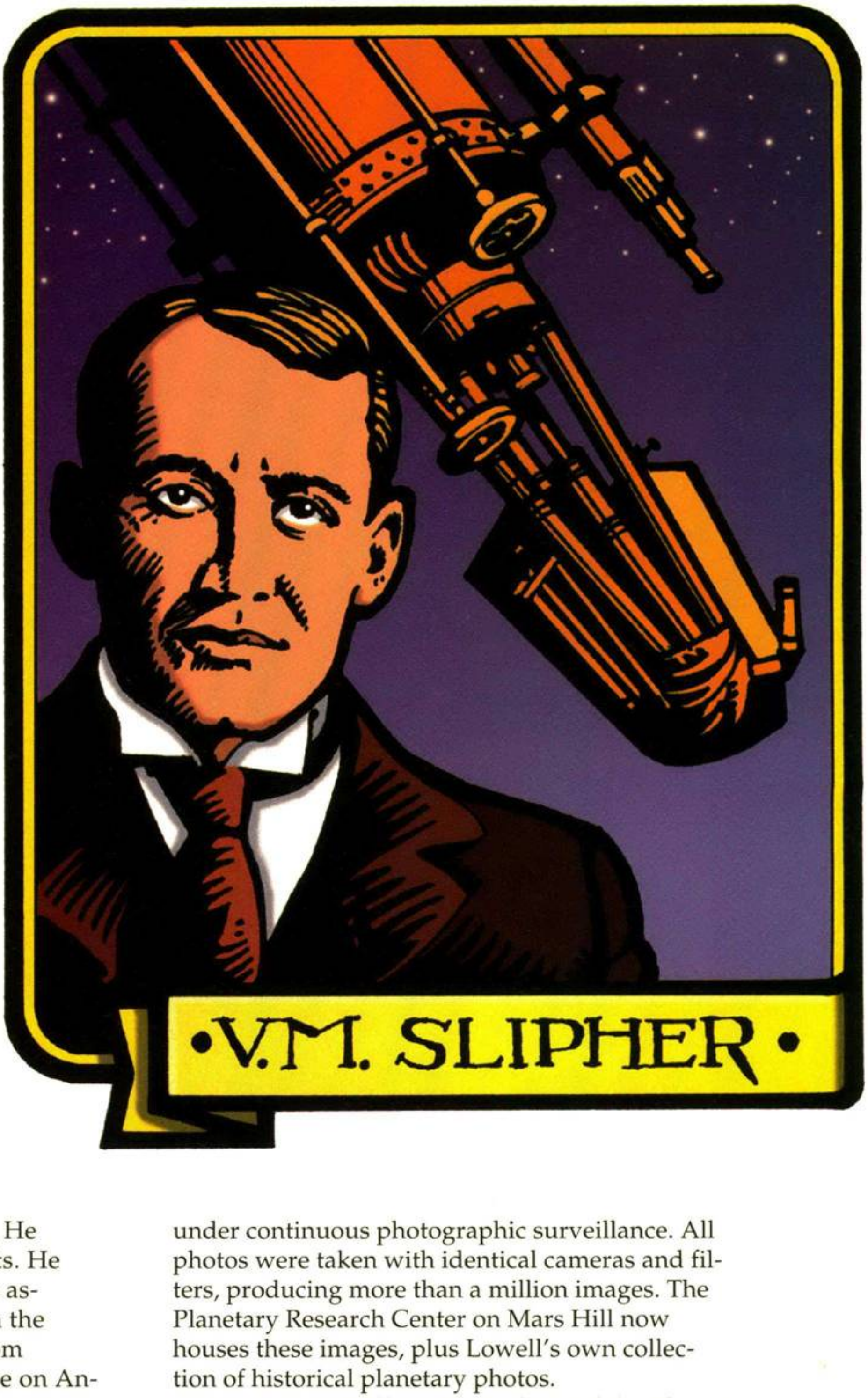
The years following the discovery of Pluto saw the observatory shift gears. In a sense, Lowell's main mission had been accomplished. True, life had not been found on Mars, but researchers no longer expected to anyway. Despite the Depression gripping the nation, work at the observatory went on. Astronomer Henry Giclas joined the staff in 1931 and began working with Tombaugh. Just in case Pluto wasn't the only Planet X around, they continued the photographic search around a strip of the zodiac 35° wide. Later, this expanded to include the entire sky visible from Flagstaff.

Meanwhile, Lampland developed a system to record and compare asteroid positions with known orbits. Using this system, Tombaugh eventually observed 3,969 asteroids, 775 of which were new discoveries. In addition to Pluto, Tombaugh also discovered five new open star clusters, one supercluster of galaxies, and a globular star cluster before leaving Lowell in 1945.

Arthur Adel had joined the staff in 1936 and was doing work that he had begun at the University of Michigan on planetary atmospheres. He discovered a "window" in Earth's atmosphere that allows 20-micron infrared radiation to reach Earth's surface. This window has allowed astronomers to study the Milky Way's nucleus as well as the heat radiation of the outer planets.

After World War II Lowell Observatory underwent a significant change. Until 1948, funds from Percival Lowell's endowment covered all expenses. But after the war it became clear that additional outside money was needed. The observatory signed a contract with the U. S. Weather Bureau to study the atmospheres of Mars, Jupiter, and Saturn. Later, the observatory contracted with the Air Force to study the constancy of sunlight reflected from Uranus and Neptune.

When Slipher retired, the new head, John Hall, brought Lowell Observatory firmly into the modern era. Director until 1977, Hall expanded Lowell's facilities and greatly strengthened its research staff. He bought new telescopes and instruments. He improved old ones. He invited foreign astronomers to visit — and he dealt with the growing problem of light pollution from Flagstaff by establishing a dark-sky site on Anderson Mesa about 12 miles south of the city.

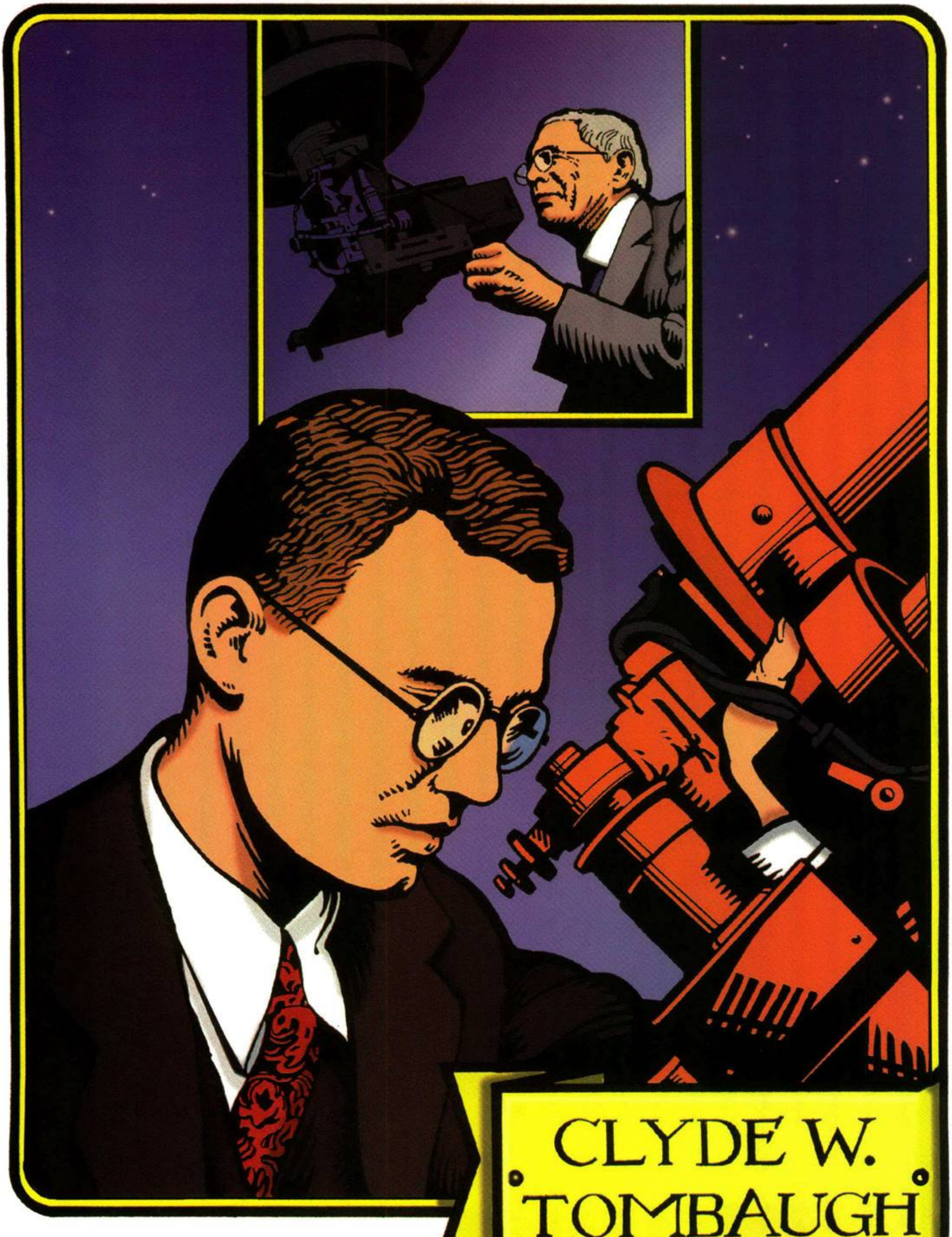


Racing into Space

Part of the new excitement stemmed from the space program and the research coming from it. In the 1960s, Lowell Observatory organized and operated an International Planetary Patrol program with NASA funding. The observatory found and staffed the sites, built the cameras, installed telescopes, and processed the film. Astronomers at Lowell and at six other locations around the world kept Mars and Jupiter under continuous photographic surveillance. All photos were taken with identical cameras and filters, producing more than a million images. The Planetary Research Center on Mars Hill now houses these images, plus Lowell's own collection of historical planetary photos.

Astronomer William Baum directed the Planetary Research Center from 1965 until 1991. He and his staff catalogued the photo archives and film from the planetary patrol network. These photos have provided data on clouds, dust storms, and atmospheric circulation patterns on Mars and other planets. Astronomers have also used the photos to study Saturn's rings and Jupiter's rotational velocity.

By the 1970s, Lowell Observatory had grown to have a scientific staff of almost a dozen, using tools and technology quite different from those in Percival Lowell's original observatory on Mars Hill.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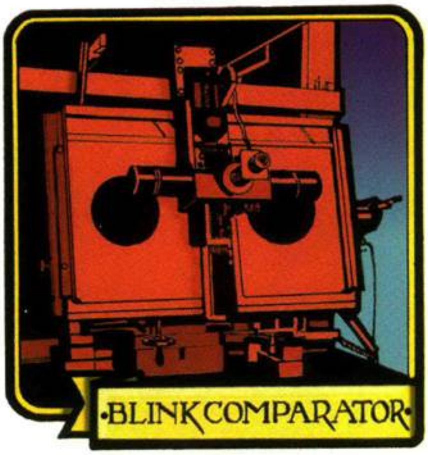
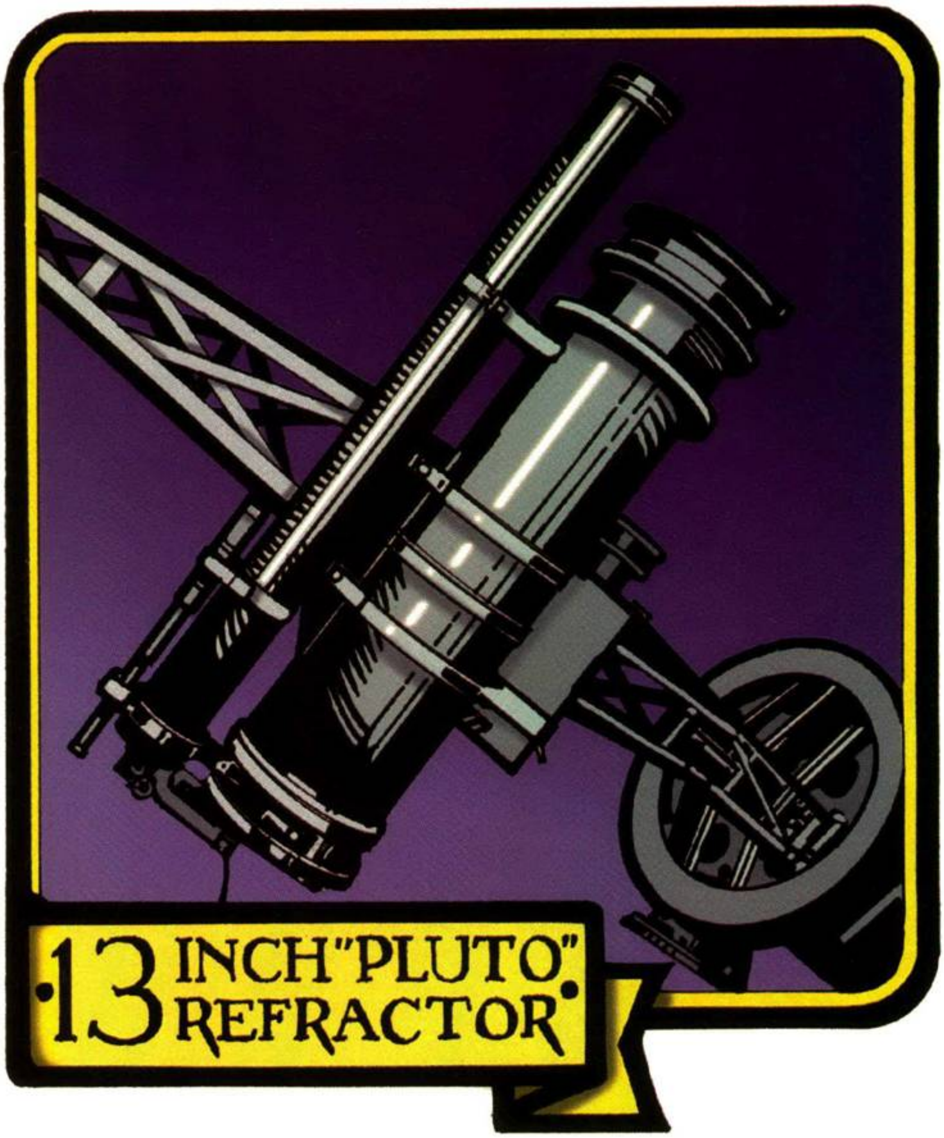




Alongside the venerable 24-inch Clark refractor and the 13-inch Pluto telescope are other instruments. There's an 18-inch refractor for observations of star positions and a 21-inch reflector for studying the luminosity of the Sun.

The Anderson Mesa station, used under permit from the U. S. Forest Service, currently houses three telescopes, the largest being the Perkins 72-inch. In 1961 Hall proposed to Perkins Observatory in Ohio that it move its large reflector to better skies in the Southwest. They agreed. Lowell Observatory built a dome for it and now operates the telescope, which Lowell and Perkins astronomers share for deep-sky research.

Near the 72-inch dome stands the highly versatile 42-inch telescope, which Hall was instrumental in acquiring and which is now named for him. Astronomers use it for CCD imaging, spectroscopic monitoring of stellar and solar activity, and photometry of comets. The third telescope is a 31-inch reflector originally used by the U. S. Geological Survey for lunar mapping. The observatory refurbished it in 1989 and 1990, and it is now used by Lowell astronomers together with undergraduate students from a consortium of small colleges. With new computerized detectors, astronomers can use it for work that only much larger telescopes could do a decade ago.

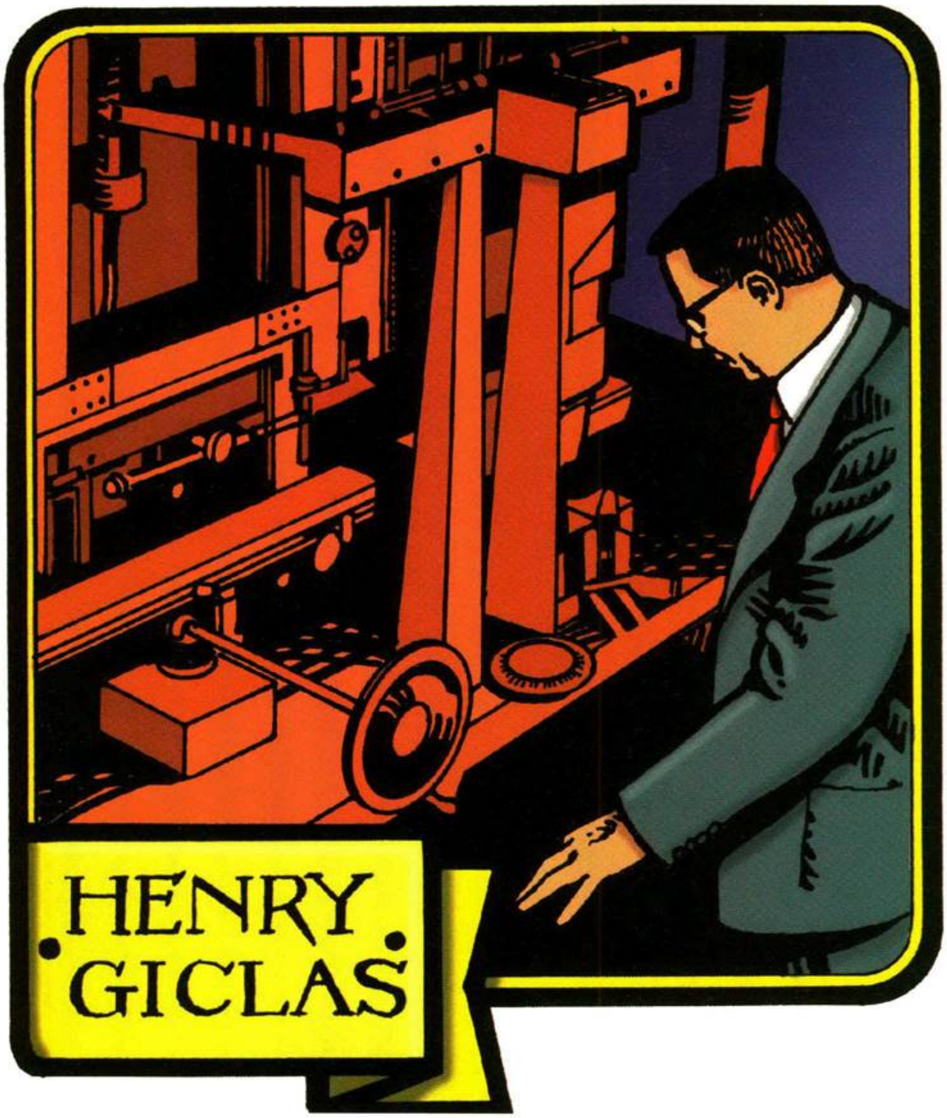
A new generation of instrument is also under construction on Anderson Mesa. It is an optical interferometer, a high-resolution instrument that will work like a visible-light version of the Very Large Array radio telescope. Lowell is building this instrument for the Naval Research Laboratory and the U. S. Naval Observatory, with astronomer Nat White serving as project manager.

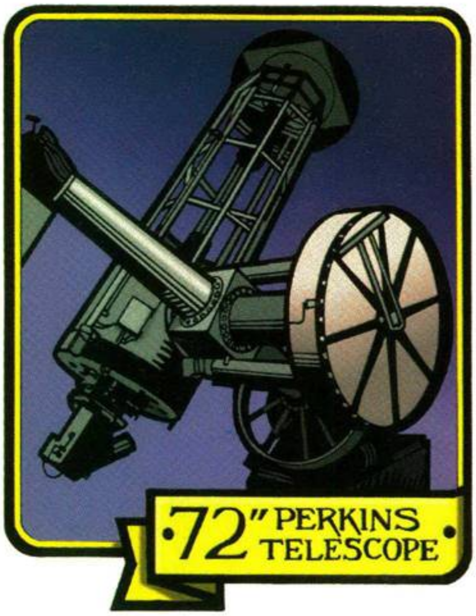
Probing Planets & Moons

A snapshot of Lowell Observatory today reveals an extraordinary breadth of research interests. Many center on the solar system, reflecting the observatory's heritage.

Marc Buie, for example, often explores territory that might be called Lowell's own — Pluto (and its moon Charon). Recently, Buie and collaborator David Tholen of the University of Hawaii drew a map of this planet, which lies so far away that it is never more than a dot of light in a telescope. Their "pencil"? The moon Charon, which recently passed in front of and behind Pluto in a series of mutual eclipses. Knowing where Charon was relative to Pluto and using the minute changes in brightness let Buie and Tholen convert the telescopic magnitudes into a map of bright and dark areas on Pluto. Buie is also using the Hubble Space Telescope to study the planet.

Lowell astronomers have also been involved in studying planetary occultations, which occur when a solar system body moves in front of a





background object, cutting off its light. The technique can reveal surprises: An occultation of a star by Pluto in June 1988 showed that Pluto had an atmosphere, which astronomers had suspected but never proved. An occultation in March 1977 led Lowell's Robert Millis (the observatory's present director) and his colleague Cornell University's Jim Elliot to discover the ring system around Uranus.

Millis has collaborated with Lowell comet astronomer David Schleicher on a pathbreaking study of Comet Halley that revealed a 7.4-day rotation for its nucleus. They have also investigated the group properties of comets, examining some 83 comets observed over the last 18 years, as well as making detailed scrutiny of specific ones.

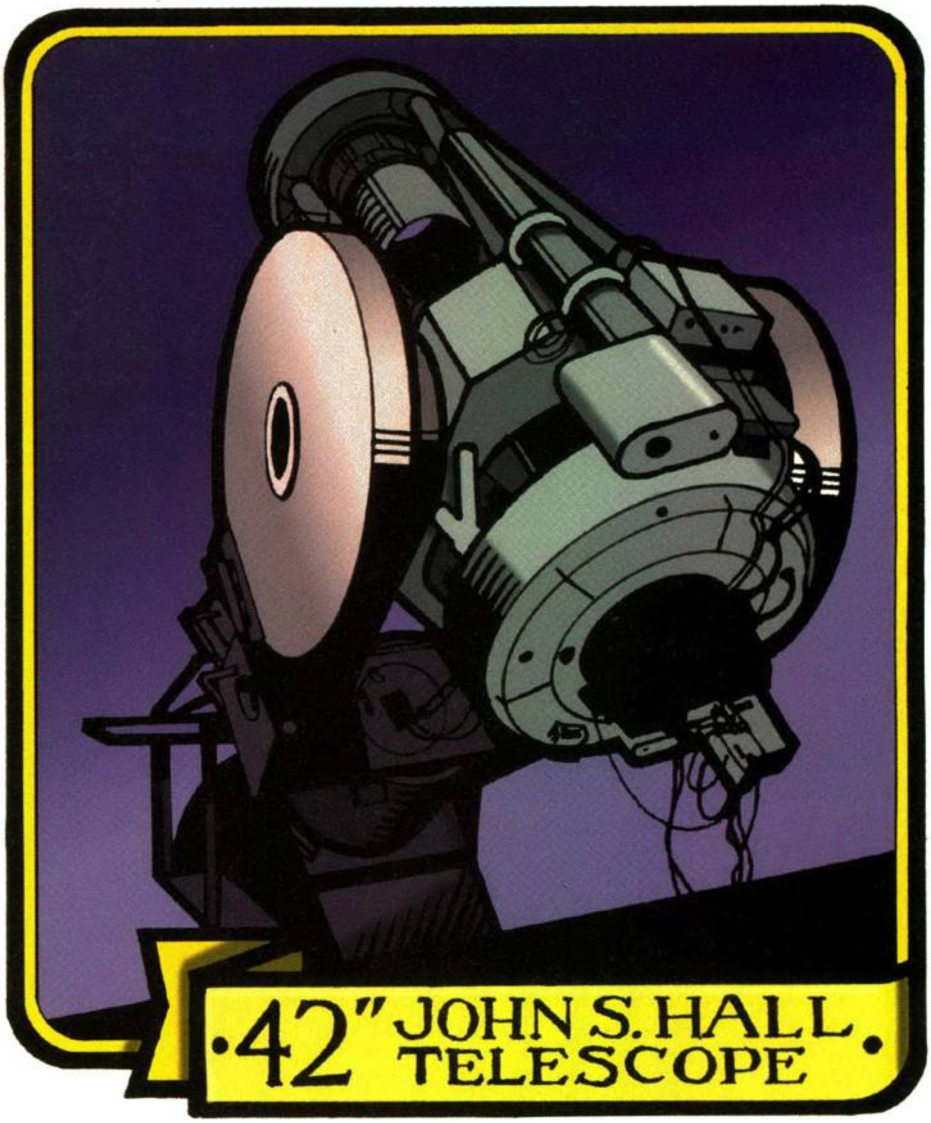
Lowell astronomer Edward Bowell has discovered and named about 300 out of the 15,000 or so known asteroids. He works with Gene and Carolyn Shoemaker, who joined the Lowell staff last year after Gene retired from the U. S. Geological Survey. Much of their work focuses on the physical nature and orbits of asteroids, both those that come near Earth and ones in the main belt between Mars and Jupiter. Bowell is supervising the installation on Anderson Mesa of a new Schmidt camera with a large-format CCD detector. It will hunt specifically for Earth-approaching asteroids.

Jupiter's eruptive moon Io draws the attention of Lowell astronomer John Spencer. His work, usually done with the Hubble Space Telescope, involves studying Io's volcanic hot spots — where they are and how they change (see "The Violent Volcanos of Io," May 1993). He's hoping to understand the moon's long-term variations in volcanic activity and also to develop a detailed model for its eruptions.

Other Stars, Other Suns

But the research interests of Lowell astronomers don't stop at the edge of the solar system. Wes Lockwood, Brian Skiff, Don Thompson, and Jeff Hall are studying stars similar to the Sun to compare their activity with it. This should provide insights into how the Sun's luminosity varies with sunspot activity, research important to understanding global warming and the greenhouse effect on Earth. So far, results show that stars older than our Sun become brighter as their magnetic activity increases, and younger stars seem to vary more in magnitude and number of starspots.

Lowell astronomer Otto Franz has been studying binary stars since joining the staff in 1959. He measures positions of the component stars of binary pairs to calculate their orbits. Most recently, with Lowell's Larry Wasserman, he has been using the fine-guidance sensors on the Hubble Space Telescope to study binary stars. From this work, he can derive the stars' masses. Mass determines a star's luminosity and temperature, and it foretells how long a star will live and how it will die.



Lowell's Diedre Hunter studies irregular galaxies to determine how fast stars form and what governs their rate of formation. Astronomers know that violent star birth in one portion of a galaxy may trigger more stars elsewhere. She is studying our Galaxy's satellites, the Magellanic Clouds, and another irregular galaxy 15 million light-years away. Compression waves called spiral density waves appear to trigger the formation of stars in spiral galaxies like our Milky Way. These waves don't exist in irregular galaxies, and theories of star formation must account for this.

William Baum retired from Lowell in 1991 but has kept active with research in several fields, one being elliptical galaxies. These are ancient and rich in heavy elements but have no areas of star formation within them. The Coma cluster of galaxies contains many ellipticals, and this is the group that Baum is studying. Baum, Hunter, and Jon Holtzman work with the Hubble Space Telescope's Wide Field/Planetary Camera. They expect the newly enhanced optics will let them analyze individual stars within the distant ellipticals. Holtzman, using the Hubble cameras, has also made what may be the first detection of very young globular clusters.

Into the New Century

As Lowell Observatory greets its centennial, it faces a situation that Percival Lowell never had to deal with: a steady stream of visitors. To explain the work of the observatory and its instruments, a new visitors' center has been built on Mars Hill, not far from the mausoleum that shelters Percival Lowell's grave. Funded mostly by private donations, the building provides modern exhibits and will include a 100-person lecture hall. A centerpiece display, sponsored by the National Science Foundation, offers visitors an interactive and computer-based look at the exhibit called "Tools of the Astronomer."

What began a century ago as one man's private obsession has blossomed into a wide-ranging institution on the cutting edge of today's astronomy. For 100 years, Lowell Observatory has made substantial contributions to the science of astronomy. The 21st century will hold many exciting new discoveries, and if the past is any indication, the observatory will participate in many of them. □

Bruce Bond is a writer, amateur astronomer, and commercial illustrator living in the Milwaukee area.

ALL EYES ON

THE COMET CRASH

Hundreds of astronomers are preparing to watch Comet Shoemaker-Levy 9 smash into Jupiter, hoping to catch a rare glimpse at the structure and chemistry of the Giant Planet's atmosphere.

by David Bruning

A two-kilometer block of ice hurtles toward the surface of Jupiter at over 200,000 kilometers per hour. It forms a bright streak across the Jovian sky before plunging into the cloud layers. Boom! roars the ensuing shock wave. The meteor punches a hole in the atmosphere as it plummets deeper. Gas rushing up the sides heats up tenfold to 3000 kelvins and soars 3,000 km above the clouds. The hot plume resembles a nuclear fireball.

When the meteor finishes burying itself far below the cloud tops, the impact will have released the energy of up to 10 trillion tons of TNT. That's hundreds of thousands of times larger than the Tunguska impact that devastated Siberia at the turn of this century. Yet the impact is tiny compared to the boisterous dynamics of Jupiter's atmosphere. As a result, the plume of hot material thrown up by the falling comet lasts just a few short minutes.

Earthbound observers can't see the event because it occurs on Jupiter's nightside. They can detect it though and wait patiently. There it is — a brief flash of light reflected faintly off the planet's rings and one of the planet's satellites. As the region rotates into view, they look for signs of the impact. But Jupiter's thick atmosphere has swallowed the cometary fragment whole. Only one sign of the impact remains: a faint glow from residual heat that warms the site and is detectable only by astronomers who know Jupiter's atmosphere well.

So starts nature's grand experiment in cometary impacts — the crash of Comet Shoemaker-Levy 9 into Jupiter this July. Impacts have been seen before in our solar system (Voyager 1 recorded a fireball at Jupiter), but never before have we been so forewarned and prepared to view such an event. Or events, because this impact will repeat at least 20 times over an interval of 5$^1/_2$ days.

The beginnings of the experiment were revealed in March 1993 when Carolyn Shoemaker noticed a "squashed" comet on a photo taken by Eugene Shoemaker and David Levy with the 0.4-meter Schmidt telescope at Palomar Observatory. They contacted Jim Scotti at the University of Arizona's Spacewatch program who used a 0.9-meter telescope on Kitt Peak, outside of Tucson, to verify the new object. He discovered that the comet wasn't squashed — it consisted of individual fragments.

Scientists slowly unraveled the nature of the comet's motion, discovering that the object orbits not the Sun but Jupiter. More startling was the news from Brian Marsden of the Smithsonian Astrophysical Observatory in Boston — the comet would impact Jupiter in July 1994.

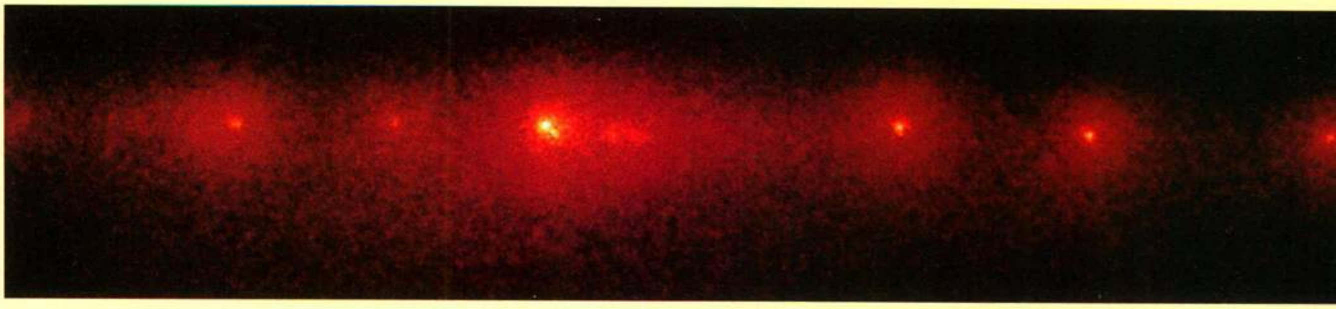
Researchers tracking the comet's orbit back in time uncovered a second bit of startling news — the comet had already skimmed a mere 20,000 kilometers above the Giant Planet's cloud tops on July 7, 1992. This close encounter subjected the solid body to gravitational forces that shattered the comet into more than 20 large fragments and thousands of smaller ones. Jay Melosh of the University of Arizona's Lunar and Planetary Lab says the nucleus must have been very fragile. "If a cookie were that weak," he says, "it would crumble on the plate."

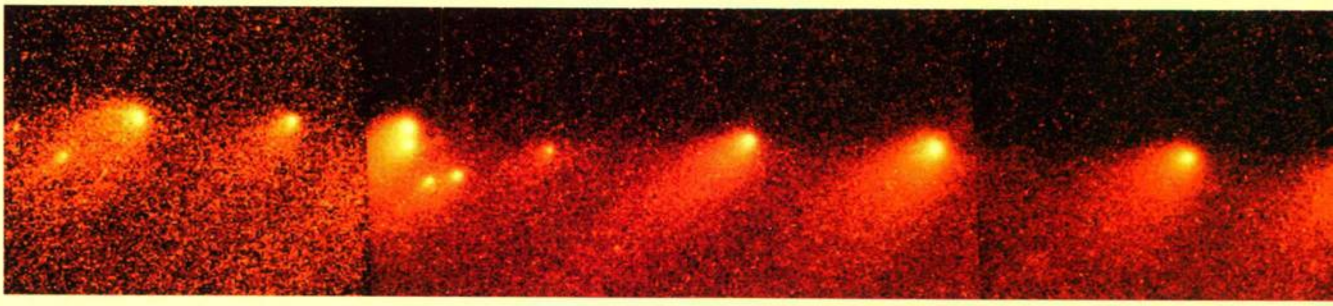
Tracking the orbit back further, researchers found that Jupiter captured the comet about 100 years ago — and tracking it back even further should reveal whether Shoemaker-Levy 9 started as an icy comet or a rocky asteroid. Ted Bowell and Lawrence Wasserman of Lowell Observatory in Flagstaff, Arizona, suggest that it was an asteroid that strayed from the outer belt of asteroids located between Mars and Jupiter.

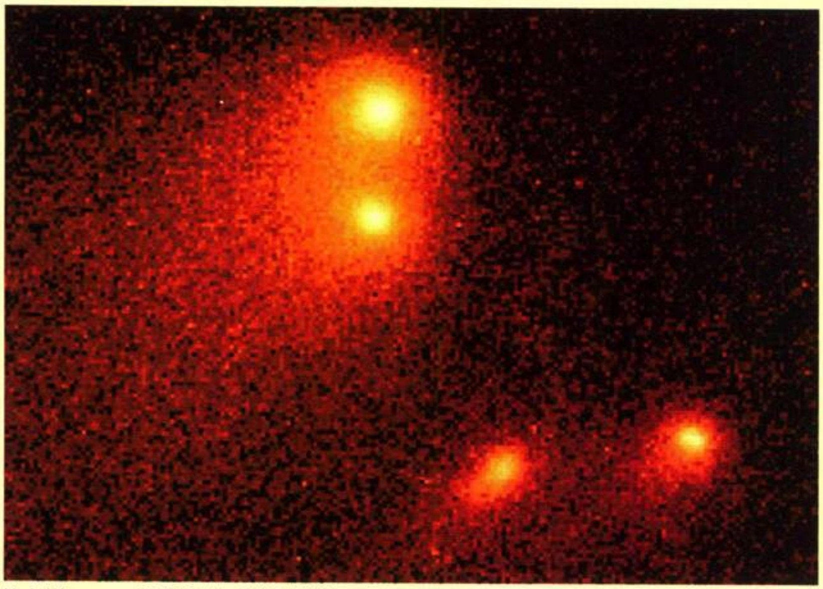
Lance Benner and Bill McKinnon of Washington University in St. Louis disagree. They admit that the object did

THE EVENT OF A LIFETIME — Comet Shoemaker-Levy 9 as it crashes into Jupiter in July will provide planetary scientists with rare glimpses into the structure and chemistry of the Giant Planet's atmosphere.

Pat Rawlings







H. A. Weaver and T. E. Smith, STScI/NASA

AS THE COMET FINISHES its last orbit around Jupiter, the fragments continue to spread. Hubble Space Telescope images taken in July 1993 (top) and late January 1994 (above) reveal that some of the fragments (called P and Q) have split into pieces (see close-up at left).

spend some time in the region of the outer asteroid belt, but claim that the object is a comet that got bumped into that orbit and then into one around Jupiter. Alan Boss of the Carnegie Institution of Washington has calculated the object's density from the physics of the breakup. He finds the density is too low for a rocky asteroid and concludes that the object is probably an icy comet. But because of the scrambling effect Jupiter's gravity has had on the comet's orbit Scotti says, "We are likely to never know for certain where the progenitor came from."

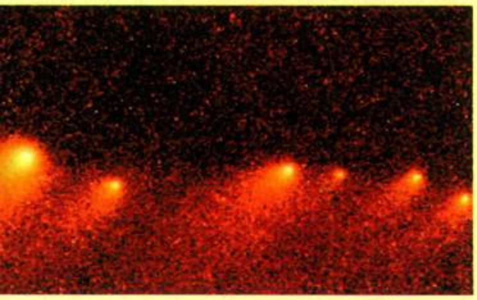
The latest orbital calculations indicate the first fragment (called A or 21) will impact on July 16 and the last (W or 1) on July 22. The five-and-a-half-day interval between the first and last impacts occurs because the fragments have spread 28 million kilometers apart during the two years since the comet broke apart.

The fragments will hit around 44° south latitude (roughly 20° south of the Great Red Spot) and about 6° behind the limb of Jupiter as seen from Earth. Only one observatory will be able to view the impact site directly — the spacecraft Galileo, which is on its way to a December 1995 encounter with Jupiter. It will take 10 minutes for Jupiter's rapid rotation to bring this area into view for earthbound observers. While infrared astronomers can start to observe immediately at this time, visible light observers will have to wait until the site moves into sunlight. Because Jupiter is past opposition, the Sun lies west of Jupiter so the nightside creeps about 10° over the planet's eastern limb. It will take another 15 to 20 minutes for the site to move into sunlight.

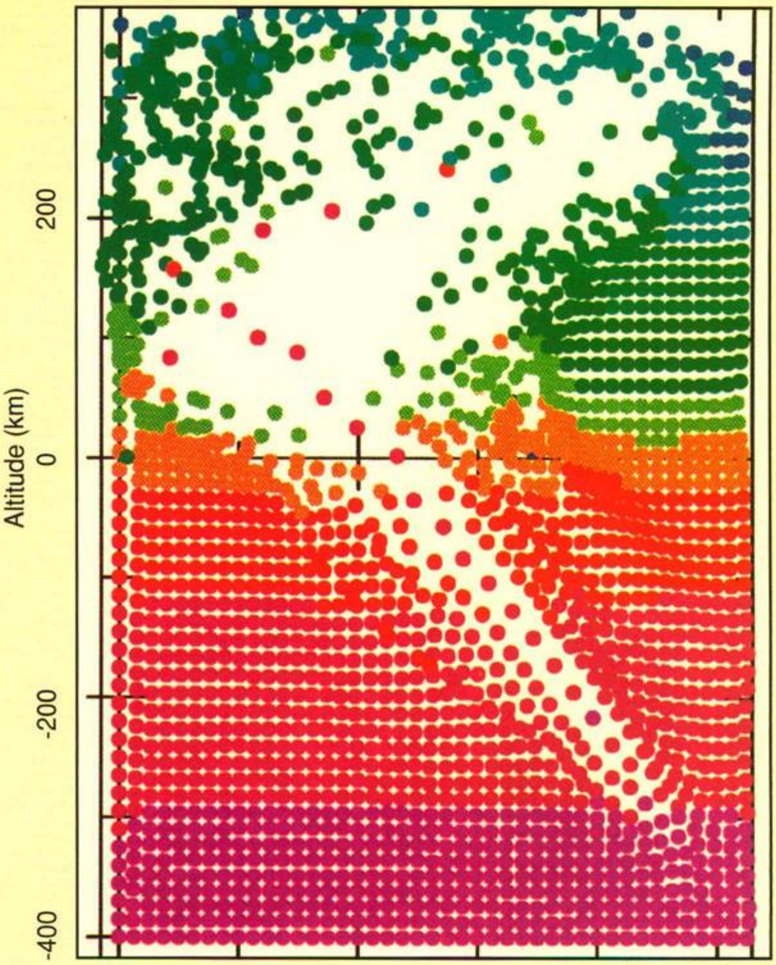
Although the fragments will all hit at about the same latitude and at about the same distance from the day-night line of Jupiter's surface, the impacts will scatter nearly evenly in longitude. The impacts all hit along a zone, a band of bright turbulent material (see the illustration on page 44). Spots and long-lived features can't exist in such a region and disappear within just a few weeks when they do erupt. So any disturbances created by the impacts will probably be short-lived.

But will the impacts create a disturbance? The thick atmosphere of Jupiter may not react in a big way to the impact of a tiny comet. Theorists have attempted to model impacts for different-sized fragments to answer this question.

Tom Ahrens, Toshiko Tanaka, John O'Keefe, and Glenn Orton of the California Institute of Technology in Pasadena have developed a *"soft-catch" model*, wherein the fragment plunges to a great depth as the atmosphere slows it down. The model created by Kevin Zahnle of NASA's Ames Research Center and Mordecai-Mark Mac Low of



NINETY SECONDS AFTER IMPACT, a two-kilometer fragment will have slashed hundreds of kilometers below Jupiter's cloud tops (orange) and thrown up an equally tall plume of hot gas. Color in this plot from an impact model represents gas pressure, with magenta strongest and blue weakest.



Thomas Ahrens, et al., Caltech

the University of Chicago suggests that it's a "hard catch," with the fragment decelerating rapidly and not penetrating as deeply.

In both models an evacuated tube develops behind the fragment as it punches through the atmosphere. The displaced gas gets heated by the impact and thrown into Jupiter's stratosphere (the region above the cloud layer) to form a hot plume thousands of kilometers high. (Astronomers call it a thermal plume to distinguish it from cloud features called plumes.) Unfortunately for Earth-bound observers, the plume won't last the brief interval it takes for the region to rotate onto the visible hemisphere of Jupiter. But Galileo will have a ringside seat for viewing the plume.

Earth-bound observers may see the energy released in the plume as a flash of light reflected by Jupiter's largest and nearest satellites. If each fragment breaks up as it passes through the atmosphere, the impact's energy will be dumped high in the atmosphere. Otherwise the fragment will penetrate deep below the cloud layers and dump its energy in the lower atmosphere. The brightness of the impact's flash will depend on how much energy is released at high altitude. John Spencer of Lowell Observatory adds that the flashes reflected by Jupiter's satellites will be strongest in infrared light. In green light, the flash will be a billion times fainter than sunlight reflected by Io. But at an infrared wavelength of 5 microns, it is nearly 25 percent of the reflected sunlight.

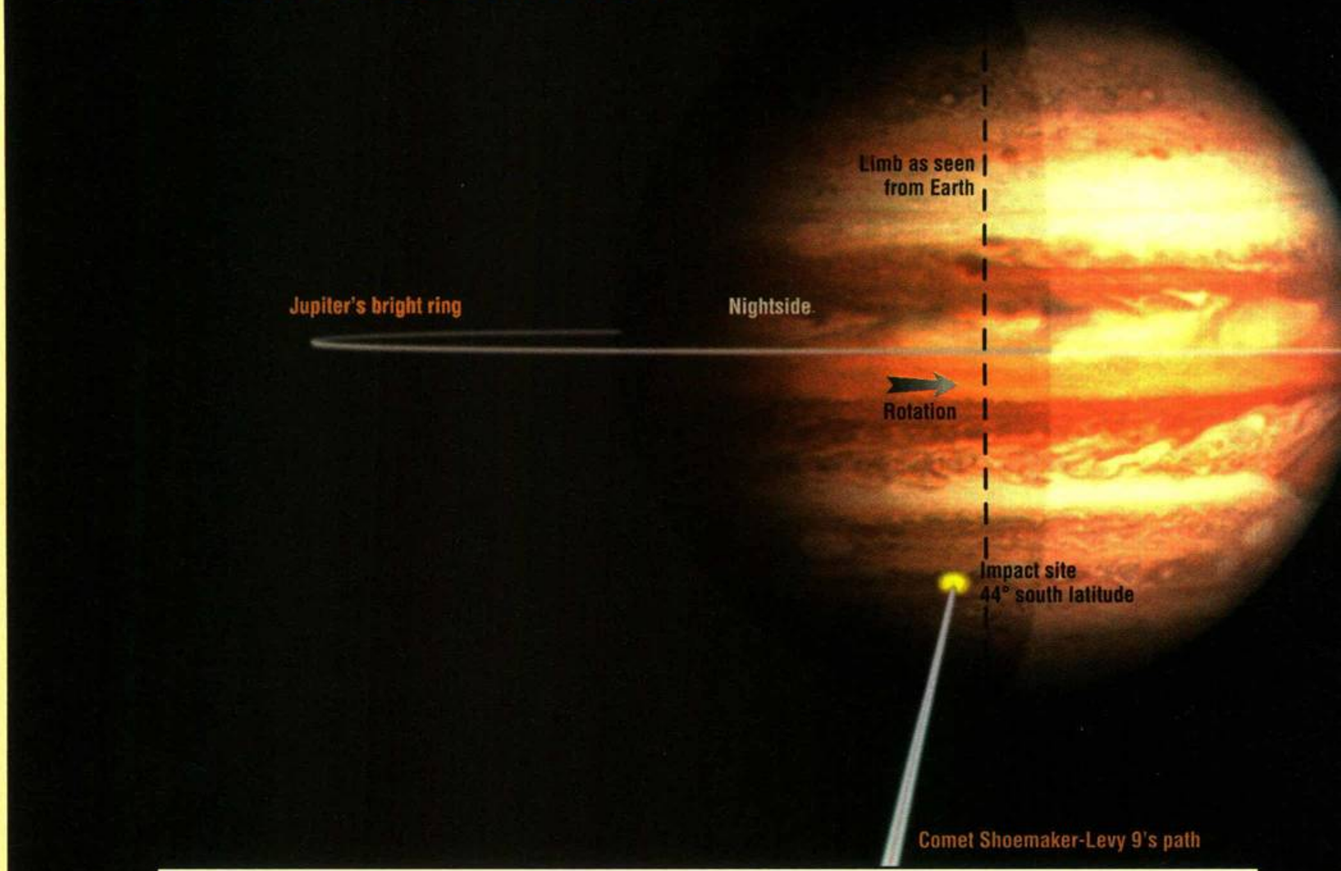
Although Ahrens' team and Zahnle and Mac Low disagree about the details of the impact and the depth of penetration, they do agree that the size of the fragment is the key to predicting what we'll see. Scotti and Melosh estimate from their calculations of the breakup that the parent comet may have been only 2.5 km in diameter, or smaller, making the fragments about 1 km across. But Hal Weaver of the Space Telescope Science Institute in Baltimore reports Hubble observations that indicate the brightest 11 fragments are 2 to 4 km in diameter, indicating the parent body was 8 km across. The difference in diameters reported is small but significant, amounting to a difference in energy release of factors of tens. Resolving the difference in size may have to wait until the impacts so astronomers can determine the amounts of energy released and deduce the sizes from model calculations.

The thermal plume and resulting flash aren't the only evidence of the impact that astronomers will look for. And a good thing too. Mac Low says that the thermal plume will be hard to see because of the low density of material. He adds, "The $64,000 question is whether the energy will run up the entry trail or go up vertically." Which way the energy flows will determine the brightness of the plume.

So observers will hunt for other disturbances in Jupiter's atmosphere. For instance, if the impact is large enough, Mark Marley of New Mexico State University says the region may ring like a bell for several hours. But it will be tough to detect, perhaps changing the temperature by just a few hundredths of a kelvin. Nonetheless, astronomers will look, just in case the predictions underestimate the impacts' effects.

With any luck, the impacts will also cause the atmosphere as a whole to oscillate, producing long waves that may enable astronomers to decipher the structure of Jupiter's atmosphere deep below the cloud levels, just as geologists use waves created by earthquakes to probe our planet's interior. The lack of information about the lowest layers is presently the greatest deterrent in developing bet-

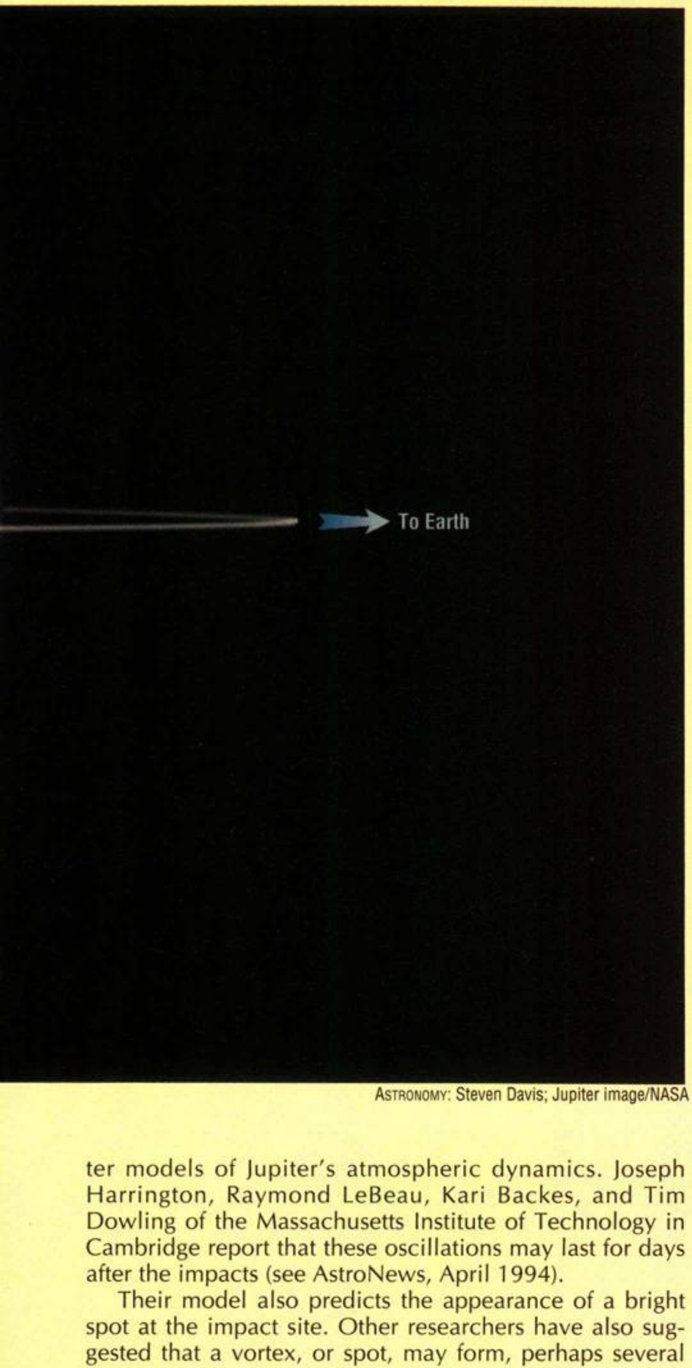
RUSHING TO DESTRUCTION


Limb as seen from Earth
Jupiter's bright ring
Nightside
Rotation
Impact site 44° south latitude
Comet Shoemaker-Levy 9's path

Impact Times

Fragment	Date (UT)*	Latitude	Angle	Satellite flash visibility Io	 Europa	 Ganymede	 Callisto
A (21)	July 16 19h26m	−43.3°	8.7°		X	X	X
B (20)	17 2h38m	−43.3°	8.5°	X	X	X	X
C (19)	17 6h29m	−43.4°	8.4°	X	X	X	X
D (18)	17 11h31m	−43.4°	8.2°	X		X	X
E (17)	17 14h38m	−43.8°	8.2°	?		X	X
F (16)	18 0h29m	−44.2°	9.4°			X	X
G (15)	18 7h12m	−44.2°	8.1°			X	X
H (14)	18 18h43m	−44.0°	8.1°	X*			X
J (13)	19 2h10m	−43.7°	6.9°	X			X
K (12)	19 10h05m	−44.4°	7.2°		E		X
L (11)	19 21h22m	−44.5°	7.6°		X		X
M (10)	20 5h31m	−43.9°	6.0°		X		X
N (9)	20 9h50m	−44.8°	7.0°		X		X
P (8)	20 14h38m	−45.0°	5.5°	X	X		X
Q (7)	20 19h12m	−44.5°	6.2°	X	X		X
R (6)	21 6h17m	−44.8°	4.4°	?			X
S (5)	21 14h38m	−44.7°	6.8°				X
T (4)	21 18h00m	−44.1°	4.8°				X
U (3)	21 21h07m	−44.1°	4.7°				X
V (2)	22 4h19m	−44.1°	4.5°				X
W (1)	22 7h41m	−44.2°	4.0°	X*			X

Orbital computations by Paul Chodas, Don Yeomans, and Zdenek Sekanina (February 23, 1994).
Subtract 4 hours for EDT; 5 hours for CDT; 6 hours for MDT; and 7 hours for PDT. "Angle" is the longitudinal distance of the impact behind the limb. Satellite flash visibility: "X" means that the satellite is in a good position to reflect a possible flash; "?" may reflect a possible flash; "E" means that the impact occurs during an eclipse of the satellite; * may occur during eclipse of satellite.



ASTRONOMY: Steven Davis; Jupiter image/NASA

THE COMET WILL STRIKE on Jupiter's nightside in a zone south of the Great Red Spot. Because the 21 major fragments have spread over millions of kilometers, impacts will occur during a five-and-a-half day interval.

ter models of Jupiter's atmospheric dynamics. Joseph Harrington, Raymond LeBeau, Kari Backes, and Tim Dowling of the Massachusetts Institute of Technology in Cambridge report that these oscillations may last for days after the impacts (see AstroNews, April 1994).

Their model also predicts the appearance of a bright spot at the impact site. Other researchers have also suggested that a vortex, or spot, may form, perhaps several thousand kilometers across. Mac Low, for one, says a spot won't form and others suggest that the only sign at the impact site will be a gentle warming of the gas.

Certainly much of the attention of astronomers and the public has focused on the impacts. But in reality we'll learn less about comets from this encounter than we will about Jupiter's atmosphere. Even if the oscillations are undetectable, another area of research will prosper — atmospheric chemistry.

The impacts will dredge material from below the cloud layer high into the atmosphere, so this is a good opportunity for planetary astronomers to examine the chemistry of Jupiter's atmosphere. This may become the first chance to detect hydrogen sulfide and other suspected but previously unseen molecules. Astronomers hope to catch a glimpse of the phosphorus that they suspect colors Jupiter's belts. The amount of water seen will detail how deeply the fragment plunged because the impact dredges water from the lower layers. The impact will also dredge up ammonia. With any luck, researchers will be able to spot a chemically disturbed region and watch it evolve.

Matching the planetary chemists in enthusiasm for the upcoming events are the ring and magnetosphere specialists. They will look for the effects of dust. Large dust wings extend in front of and behind the main fragments and tails stream from each of the fragments. The leading dust wing will largely miss the planet, while the trailing wing will hit. Dust particles near the nuclei are quite large and consist of sand to boulder-sized pieces. In the dust tails and wings, the dust is much smaller, typically less than one millimeter across.

As the comet nears Jupiter, the dust, like the fragments, will continue to spread. In fact it has spread so much that one wing has become too faint to observe and the other is barely visible. But their effect will possibly be more noticeable. Mihaly Horanyi of the University of Colorado predicts that some of the dust will form a new ring around Jupiter outside the existing rings and may add to the present outer ring called the gossamer ring.

Don't expect the rings to pop into view though. Doug Hamilton of the Max-Planck-Institut in Germany says the extra dust will add only 10 to 100 percent to the present ring mass, maintaining its faint status. Even if the rings aren't enhanced by dust, Phil Nicholson of Cornell University and other researchers hope to view the thermal plume flash reflected off the rings. How the light reflects at different angles will give scientists their best look at the nature of the rings and their dust particles since the Voyager spacecraft flybys.

Alex Dessler of the Lunar and Planetary Lab and Thomas Hill of Rice University in Houston have studied how the dust will interact with the Jupiter's magnetosphere, a region surrounding the planet and controlled by its magnetic fields. Entry of the dust into the magnetosphere may cause a rapid disruption of the dust grains by electrical forces. The greater surface area of dust resulting from the disruption may reflect a visibly greater amount of light than the dust outside the magnetosphere.

The dust will also slow high-speed electrons trapped in Jupiter's magnetic field about three Jupiter diameters from the planet's center. Normally the electrons create radio emission as they move along the magnetic fields. The dust will weaken this radiation as it slows the electrons. Radio astronomers will listen for the weakening but it may occur so slowly that it will be difficult to detect.

The uncertainty about the dust-magnetosphere interaction underscores the other questions astronomers have about how the greatest impact ever witnessed by humans will affect Jupiter's atmosphere. Will the thermal plumes be visible? Will atmospheric features change? Will the impact excite detectable oscillations of the planet?

No one knows for sure the answers to these questions, but hundreds of astronomers are gearing up at over 35 major observatories to witness every possibility, just in case the undetectable becomes detectable. And not just from the ground. Voyager 2, Ulysses, Clementine, the Hubble Space Telescope, the Extreme Ultraviolet Explorer, and the International Ultraviolet Explorer will gaze at Jupiter from their vantage points in space. Astronomers are pulling out all the stops on this event — after all, nature's grand experiment is running and it's up to us to capture it. □

SKY ALMANAC

JUNE 1994

Venus Dominates the Evening Sky

June is a busy month for Venus. During the first half of the month, the brightest planet appears higher in the twilight sky than at any other time this year. But even more interesting than its brilliance and altitude is the company Venus keeps. From about June 9 to 12, the planet tracks 5° south of Gemini's brightest star, 1st-magnitude Pollux. Then on the evening of June 20, Venus passes through the northern part of the bright Beehive star cluster in Cancer.

Comet Tempel 1 at Its Brightest

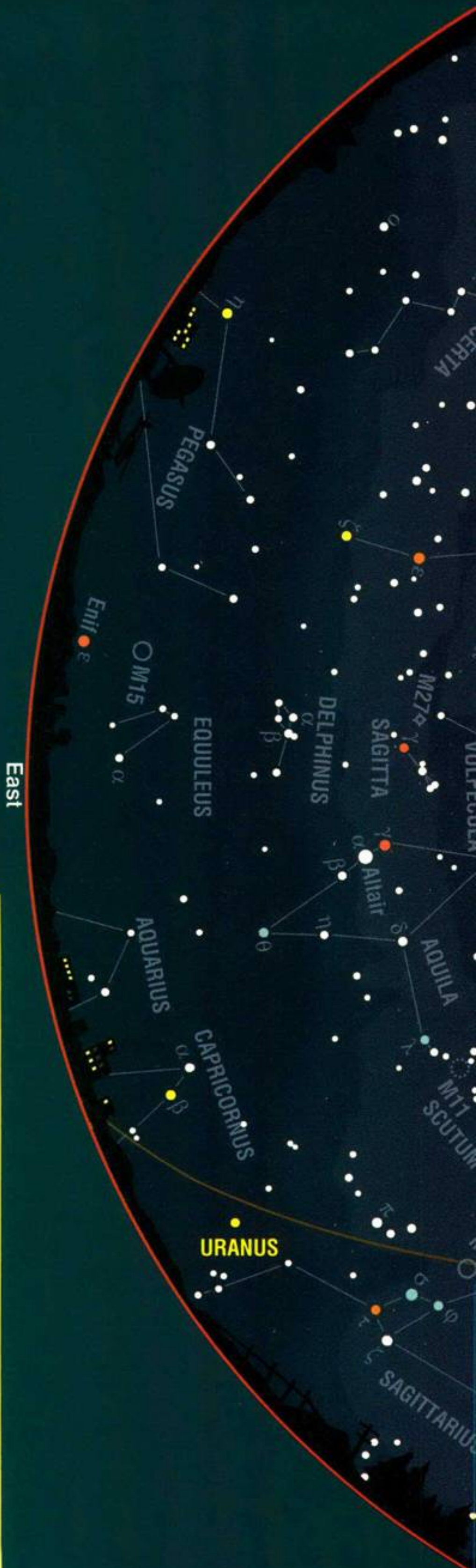
One of the best periodic comets returning to the inner solar system this year is Comet Tempel 1. This month you can watch it against the background stars of Virgo as it peaks in brightness at 9th magnitude, making a tempting target for owners of small telescopes.

Saturn's Thin Rings

Everyone knows Saturn as the Ringed Planet, but it doesn't always appear that way. In 1995 the rings will tilt edge-on to our line of sight and disappear from view. This month you can get a sneak preview of next year's action as the rings tilt just 5° to our line of sight and appear razor-thin in backyard telescopes.

Comet Crash Countdown Continues

The wait is almost over: The fragments of Comet Shoemaker-Levy 9 now are just a month away from colliding with Jupiter. With a large telescope or a CCD camera, you might catch a glimpse of the 14th-magnitude comet as it changes direction in the sky and starts bearing down on the giant planet in late June.



CALENDAR OF EVENTS

1 Last Quarter Moon is at 12:02 a.m. EDT
The Moon passes 7° north of Saturn, 8 a.m. EDT

5 The Moon is at apogee (252,086 miles from Earth), 8:39 a.m. EDT

6 The Moon passes 2° north of Mars, 1 a.m. EDT

7 Asteroid Ceres is in conjunction with the Sun

8 Asteroid Iris is at opposition

9 New Moon is at 4:26 a.m. EDT

10 Venus passes 5° south of Pollux, 1 a.m. EDT
The Moon passes 3° south of Mercury, 8 p.m. EDT

12 The Moon passes 7° south of Venus, 9 a.m. EDT

16 First Quarter Moon is at 3:56 p.m. EDT

18 The Moon passes 0.6° south of Spica, 4 p.m. EDT

19 The Moon passes 3° south of Jupiter, noon EDT

21 The Moon is at perigee (225,529 miles from Earth), 2:44 a.m. EDT
Summer solstice is at 10:48 a.m. EDT

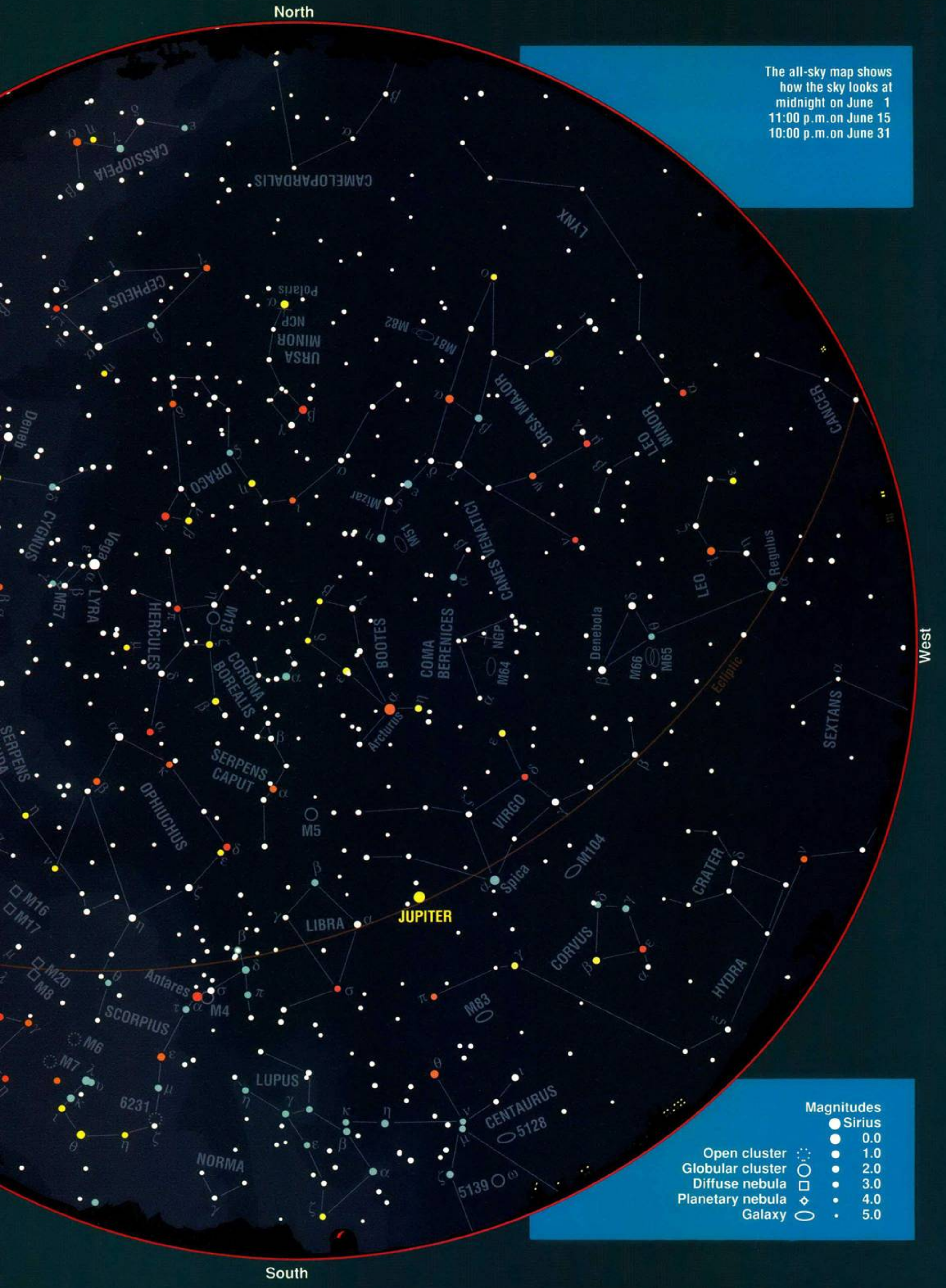
23 Full Moon is at 7:33 a.m. EDT
Saturn is stationary, midnight EDT

24 The Moon passes 4° north of Neptune, 7 p.m. EDT

25 The Moon passes 5° north of Uranus, 1 a.m. EDT
Mercury is in inferior conjunction, 6 a.m. EDT

28 The Moon passes 7° north of Saturn, 5 p.m. EDT

30 Last Quarter Moon is at 3:31 p.m. EDT


North
CAMELOPARDALIS
CASSIOPEIA
CEPHEUS
Polaris
NCP
URSA MINOR
M82
M81
LYNX
URSA MAJOR
LEO MINOR
CANCER
DRACO
Deneb
CYGNUS
Mizar
M51
CANES VENATICI
Vega
LYRA
M57
HERCULES
M13
BOOTES
COMA BERENICES
NGP
M64
LEO
Regulus
Denebola
M66
M65
West
CORONA BOREALIS
Arcturus
Ecliptic
SEXTANS
SERPENS CAPUT
SERPENS
OPHIUCHUS
M5
VIRGO
M104
Spica
CRATER
JUPITER
LIBRA
CORVUS
HYDRA
M16
M17
M20
M8
Antares
M4
SCORPIUS
M83
M6
M7
LUPUS
6231
CENTAURUS
5128
NORMA
5139
South
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows
how the sky looks at
midnight on June 1
11:00 p.m.on June 15
10:00 p.m.on June 31

SKY ALMANAC

by Deborah Byrd and Rick Shaffer

If you happen to glance at the evening sky this month, you'll find a brilliant beacon shining in the west. It's the brightest planet, Venus, now at its highest for the year after sunset for Northern Hemisphere observers.

The planet's greatest elongation — its greatest angular distance from the Sun — does not come until August. The planet is highest in our sky now because the ecliptic, the path of the Sun, Moon, and planets, appears more upright in the evening than it will in August as seen from north of Earth's equator.

The ecliptic's shallow angle keeps Venus relatively low in the Northern Hemisphere sky this summer. Even at its peak, the planet lies less than a third of the way from the horizon to overhead when the Sun goes down. Yet Venus is spectacularly bright, and many people will notice it and be surprised at such a bright object lying so near the horizon.

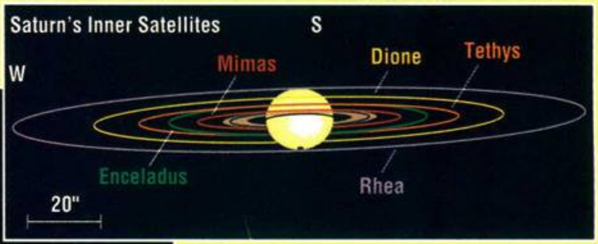
Venus lines up with two prominent stars this month, Castor and Pollux in the constellation Gemini. The stars lie above the planet when the month begins, but they descend in the west behind Venus during the month. Be sure to look for them around June 12, when Castor, Pollux, and Venus form a line with the young crescent Moon.

Later this month, Venus makes a beeline across the northern edge of the Beehive star cluster (M44). In the midst of the constellation Cancer, this cluster can be seen with the naked eye as a hazy patch on a very dark night, but it's not easily visible in the twilight sky. Use binoculars or a low-power eyepiece to follow Venus and the Beehive around June 19, 20, and 21.

(continued on page 51)

Searching for Saturn's Inner Satellites

Charles Capen



Saturn lies high in the south before sunrise on June mornings. That's good news for observers, because Earth's atmosphere is usually steadiest at the end of the night and should afford you crisp views of the ringed planet. If you haven't looked at Saturn yet this year, you'll notice that the rings don't appear as open as they did last fall. In fact they reach their narrowest opening of 1994, just 4.9°, in mid-June. If you think they look narrow now, however, just wait. Next year the rings will tilt edge-on to Earth and disappear from view!

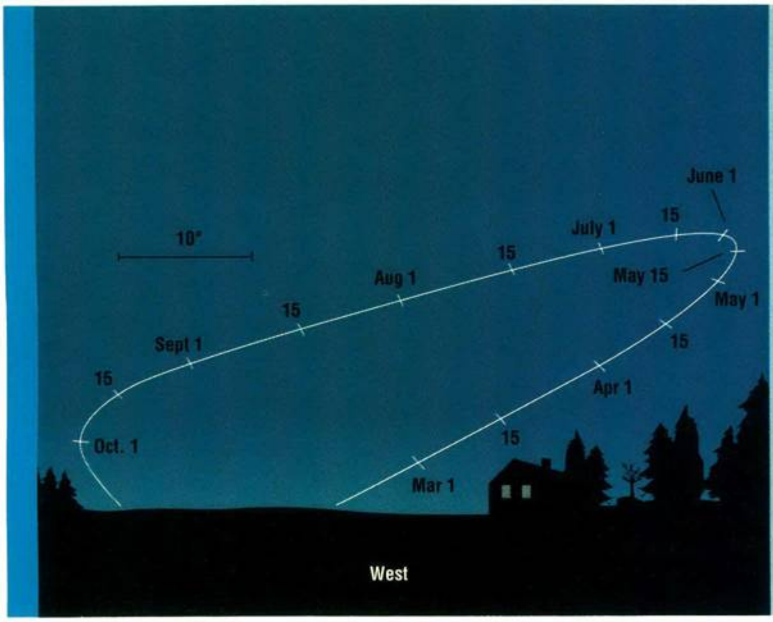
With the rings appearing nearly edge-on this month, they reflect much less sunlight in Earth's direction than normal. That means they are less likely to overwhelm the planet's inner satellites, making them easier to spot.

Of Saturn's seven satellites brighter than 13th magnitude, the hardest to see are Mimas and Enceladus, the two faintest and closest to the planet. You'll need at least a 6-inch telescope to spot Mimas, which glows at magnitude 12.9 and lies just 35 percent farther from Saturn than the outer edge of the rings. It's slightly easier to glimpse Enceladus, which glows at magnitude 11.7 from about 25 percent farther out than Mimas. The best time to look for these worlds is when they lie as far as possible east or west of Saturn. See the table for the times of greatest eastern elongation during the dark of the Moon this month. (Times are in eastern daylight time and accurate to within five minutes.) Western elongations occur halfway between.

A 4-inch scope will show you five more bright Saturnian satellites. Working out from Enceladus, they are Tethys (magnitude 10.2), Dione (10.4), Rhea (9.7), Titan (8.3), and Iapetus (11.1, though variable). Over the next couple of years, the satellites of Saturn will help make up for the less-than-inspiring views of the nearly edge-on rings.

TIMES OF GREATEST EASTERN ELONGATIONS

Mimas		
	June 9	7:20 p.m.
	June 10	5:55 p.m.
	June 11	4:30 p.m.
	June 12	3:10 p.m.
	June 13	1:50 p.m.
	June 14	12:25 p.m.
	June 15	11:00 a.m.
	June 16	9:35 a.m.
Enceladus		
	June 9	7:40 p.m.
	June 11	4:35 a.m.
	June 12	1:25 p.m.
	June 13	10:20 p.m.
	June 15	7:10 a.m.
	June 16	4:05 p.m.
Tethys		
	June 10	5:30 p.m.
	June 12	2:50 p.m.
	June 14	12:05 p.m.
	June 16	9:25 a.m.
Dione		
	June 11	1:30 p.m.
	June 14	7:10 a.m.
Rhea		
	June 11	4:10 p.m.
	June 16	4:35 a.m.



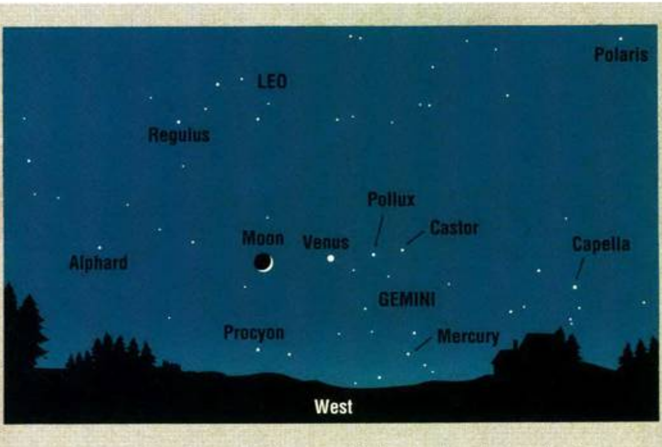
Venus is at its best . . .

As June begins, Venus climbs to its highest position in the evening sky for the year. Normally Venus' peak altitude coincides with its greatest angular separation from the Sun, or greatest elongation. But not this year.

The ecliptic — the path along which the Sun, Moon, and planets travel across the sky — makes a steep angle to the western horizon after sunset in late spring. On June 10 Venus lies 35° east of the Sun and appears 27° high at sunset. But when Venus reaches greatest elongation on August 24, the ecliptic makes a shallow angle to the horizon. The planet's 46° separation from the Sun then translates into only 17° of altitude.

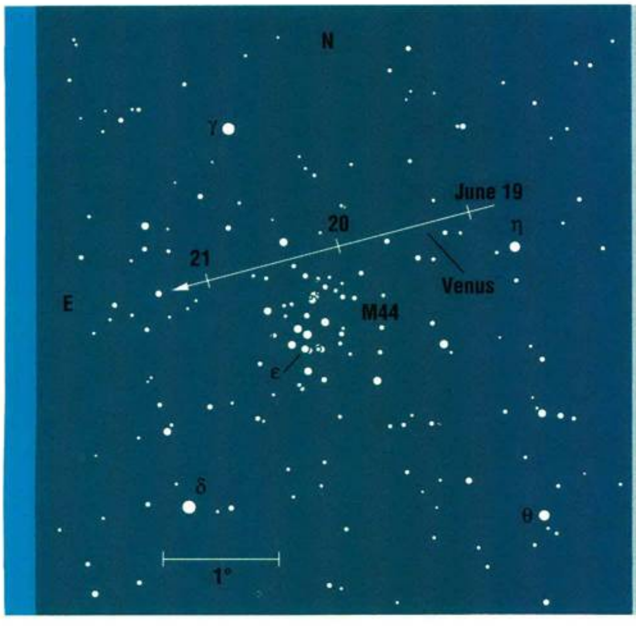
Unfortunately, Venus' telescopic appearance changes slowly this long before greatest eastern elongation. During June Venus grows only from 13" to 15" in apparent diameter and its phase wanes only from 82 percent to 73 percent lit.

. . . and passes the twins



Although Venus' telescopic appearance doesn't change much in June, its position against the background stars changes rapidly. Beginning June in central Gemini, it quickly moves east toward the two brightest stars in this constellation, Castor and Pollux. On the evening of June 9, Venus passes 5° due south of Pollux, making a pretty pair.

But the configuration three nights later is even nicer. That's when Venus lines up with both Castor and Pollux. If you head outside about 30 minutes after sunset on the 12th, you'll see brilliant Venus lying due west, orangish Pollux about 6° to the right of Venus, and whitish Castor about the same distance to the right of Pollux. (Your telescope is the best tool for comparing the colors of the three objects.) Adding to the drama is a thin crescent Moon, which on the same day happens to lie nearly on the same straight line to the left of Venus. Use both your naked eye and binoculars to follow this quartet as they sink toward the horizon over the next hour or so.



. . . and then pierces the Beehive.

Venus continues moving east and south during June. After crossing from Gemini into the neighboring constellation Cancer around June 14, it heads for one of the brightest and largest star clusters in the sky, the Beehive Cluster (M44). On the evening of June 20, Venus passes just 0.4° from the Beehive's center and actually appears to lie within the cluster's borders, a luminous queen bee that overwhelms the other hive members.

On that night Venus shines at magnitude −4.0, some ten magnitudes (a factor of 10,000) brighter than the brightest star in the Beehive. This is not an event for the naked eye — Venus renders the nearby stars invisible — but for binoculars or a telescope at low power. (You might also consider photographing the passage with a long telephoto lens.) Head out about half an hour after sunset and start watching Venus. As darkness falls you'll see more and more cluster members pop into view around Venus until planet and cluster disappear into the murk near the horizon.

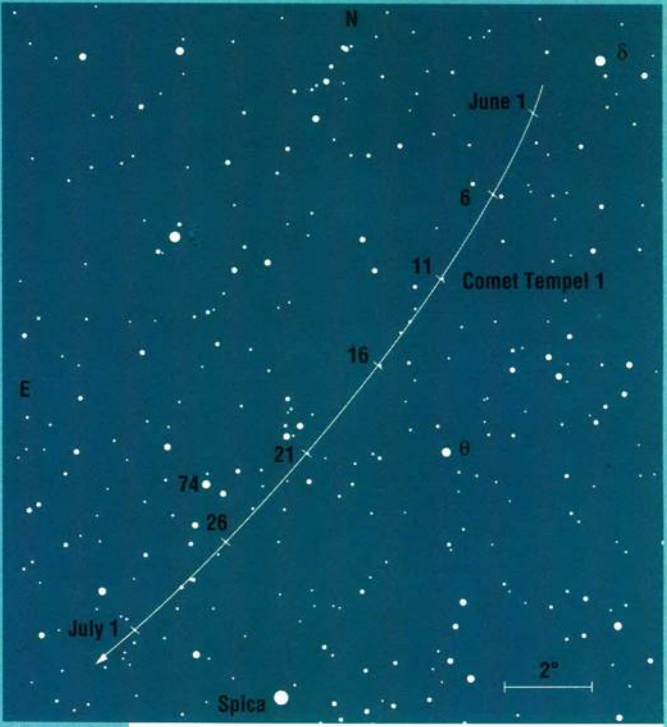
Comet Tempel 1 Peaks in Brightness

With all the hoopla this year surrounding Comet Shoemaker-Levy 9's imminent collision with Jupiter, it would be easy to overlook other comets worth your attention. And Comet Tempel 1 is definitely worth your attention. This comet shares a distinction with Shoemaker-Levy 9 — it also ran afoul of Jupiter's strong gravity. Tempel 1 was discovered in 1867 and seen again in both 1873 and 1879. It then made its first close approach to Jupiter and the giant planet slung it into a new orbit where it languished, unseen, for 14 circuits of the Sun. Then Jupiter altered its orbit again, putting it on a path more easily seen from Earth. Astronomers recovered the comet in 1967 and it's been seen at every return since.

For the last couple months, Tempel 1 has been brightening as it heads south through Virgo. In June it reaches the peak of its current apparition, glowing at 9th magnitude throughout the month and appearing well up in the southwest after darkness falls. It remains among the stars of central Virgo, moving south and east during the course of June.

At the beginning of the month you can find Tempel 1 about 2° southeast of the 4th-magnitude star Delta (δ) Virginis. It passes no other bright star until late June, when it skims 4° north of 1st-magnitude Spica. Positions in the chart and table are for 11 p.m. EDT (10 p.m. CDT, 9 p.m. MDT, and 8 p.m. PDT).

Fortunately, this part of Virgo lies far enough east of the Virgo cluster of galaxies so you won't have to worry about confusing a galaxy for the comet. The brightest galaxies near Tempel 1 glow at about 12th magnitude, some three magnitudes fainter than the comet. But the comet will look like a galaxy, appearing as a fuzzy ball of light. Ninth-magnitude comets seldom show much tail, but examine it at very low power anyway — comets tend to behave in their own way and not as we humans expect them to.



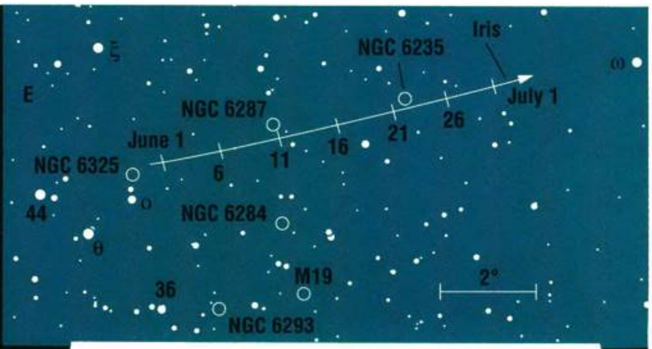
COORDINATES FOR COMET TEMPEL 1

Date	R.A. (2000)	Dec.
June 1	13h01.8m	2°12'
June 6	13h05.5m	0°21'
June 11	13h10.2m	–1°35'
June 16	13h16.0m	–3°33'
June 21	13h22.7m	–5°33'
June 26	13h30.2m	–7°35'
July 1	13h38.6m	–9°36'

Looking for Asteroid Iris

The brightest asteroid of June is 7 Iris, which peaks at magnitude 9.2 when it lies opposite the Sun on the night of June 8/9. This month the 130-mile-wide asteroid moves slowly northwest against the background stars of southern Ophiuchus, in the western reaches of the Milky Way. Although it doesn't come close to any bright stars, Iris passes less than 1° from two bright globular clusters. On the night of June 11/12, it lies next to the 10th-magnitude globular NGC 6287, while on the night of June 23/24, it passes just south of the 9th-magnitude globular NGC 6235.

You should be able to spot Iris with the help of the finder chart or table of coordinates at right, which show the object's position at 11 p.m. EDT (10 p.m. CDT, 9 p.m. MDT, and 8 p.m. PDT). If you have trouble picking it out from the background stars, however, center your telescope where the object should be and sketch or photograph the field of view. Then observe the same field a night or two later and look for the "star" that has changed position. That is Iris.



COORDINATES FOR IRIS

Date	R.A. (2000)	Dec.
June 1	17h15.2m	–23°31'
June 6	17h09.9m	–23°17'
June 11	17h04.6m	–23°02'
June 16	16h59.3m	–22°46'
June 21	16h54.2m	–22°29'
June 26	16h49.5m	–22°13'
July 1	16h45.2m	–21°57'

In early June, we catch Mercury in the midst of its best evening apparition of the year for Northern Hemisphere observers. Mercury is recognizable because it is reasonably bright and not too far below and right of Venus after sunset. Look on June 10, when Mercury appears near the young crescent Moon, making it easier to spot. Afterward, the innermost planet drops into the Sun's glare, passing between the Sun and Earth on June 25.

Saturn is stationary in front of the stars of Aquarius on June 24. This is your signal that the best time of year to watch the planet is beginning. Saturn ascends over the eastern horizon earlier with each passing night and by the end of June it is rising around midnight. Saturn comes to opposition — when it rises as the Sun sets and appears brightest for the year — in early September.

The naked eye is enough to see Saturn, but you'll need binoculars to spot Comet Tempel 1 and the asteroid Iris. This month Tempel 1 is an evening object in Virgo. Glowing at 9th magnitude, it is predicted to be the third brightest comet of the year. Iris reaches opposition on the night of June 8/9, when it is a 9th-magnitude object in southern Ophiuchus.

A good project for beginning stargazers — or for old-timers — is to gaze toward two open star clusters in the constellation Scorpius, numbers 6 and 7 on the list of "objects to avoid" compiled by the famous comet hunter Charles Messier. M6 and M7 are easy to find between the teapot asterism of Sagittarius and the tail of Scorpius. The clusters are best seen around midnight, a vivid reminder that summer's wonders are back with us for another observing season.

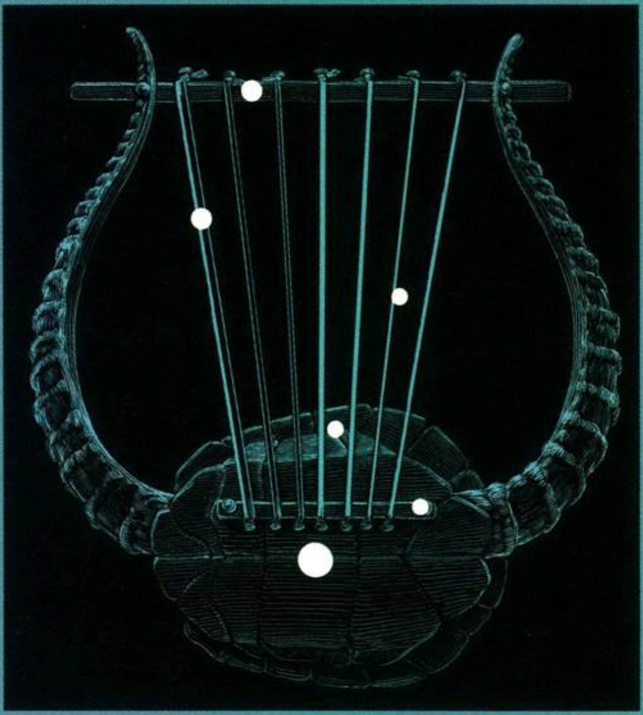
June's Planets

Mercury is the bright object near the western horizon after sunset. It is just below and to the right of a brilliant object, the planet Venus.

When the month begins, Mercury shines at magnitude 0.7, and as the days pass it

THE STARRY SKY

by Deborah Byrd



Keith Ward

On June evenings, cast your gaze toward the northeast for a heavenly display of perfect geometry: a tiny triangle atop a parallelogram. This is the diminutive constellation Lyra, which represents the Lyre belonging to the legendary poet and musician Orpheus.

According to legend, one day Hermes, the messenger god of the Greeks, found a tortoise shell while walking on the beach. He stretched seven strings across it and plucked them to produce a sweet sound. Later he traded his invention with the sun-god Apollo, who in turn gave it to his mortal son Orpheus. The story says that neither mortals or beasts, nor the gods themselves could turn away when Orpheus began playing the lyre.

But, as is true in all Greek tragedies, Orpheus' life took a sad turn. His wife Eurydice died, and Orpheus followed her into the underworld, playing the lyre as he went. Hades, who ruled the underworld, wept tears of iron on hearing Orpheus play and released Eurydice on the condition that Orpheus not look back until they reached Earth's surface. They set out, but Orpheus could not hear his lover's footsteps behind him. Breaking his vow, he turned back to look for her and saw her standing there, more beautiful than ever. She called to him and then vanished forever into the mists of the underworld.

The constellation we associate with Orpheus' Lyra possesses one of the sky's brightest stars. This is Vega, (Alpha [α] Lyrae), which shines at magnitude 0.0. From mid-northern latitudes, Vega passes nearly overhead on summer evenings. It is one of three bright stars, each belonging to a different constellation, that form the large asterism known as the Summer Triangle.

Because Vega is so bright, people notice this star. The early Romans marked the beginning of autumn by the day it slipped below the western horizon at dawn. Vega also was the first star ever to be photographed, by astronomers at the Harvard College Observatory on July 17, 1850.

Thousands of years from now, Vega will be even more noticeable. That's because Earth's 25,800-year precession cycle causes the north celestial pole to trace a slow circle among the stars, and for a period of several hundred years during this cycle Vega takes a turn at being the pole star. Vega was the pole star around the end of the last ice age, when civilization dawned. Who knows what human culture will be like when Vega is again the pole star 12,000 years from now? Then, regardless of what lies below, the northern heavens will turn around a pole star of unsurpassed brilliance.

There are interesting telescopic sights in Lyra, too. One is M57, the Ring Nebula. These glowing gases are the outer layers of a star that puffed off its atmosphere thousands of years ago when it died. This type of object was dubbed a "planetary nebula" by early telescopic observers, who saw it only as a slightly greenish disk, like that of the newly discovered planets Uranus and Neptune. Today, even a six-inch telescope will show you the nebula's ring shape.

Also, look for Epsilon Lyrae, the "double-double" star. Some claim to see a cigar-shape with only their naked eye. Binoculars with their low magnification show two stars, but a peek through a small telescope reveals that each of the two stars is also a double star. All four stars shine at nearly the same brightness and all are gravitationally bound. They are a wonder of the Galaxy — a sure stop on a scenic tour of the Milky Way — located 200 light-years away.

becomes increasingly harder to see, partly because it is getting fainter and also because it is sinking toward the Sun's glare.

This month Mercury gives telescopic observers a view of its rapidly changing phases. When Mercury is about to pass between us and the Sun, its lighted half faces increasingly away from our direction. Mercury's inferior conjunction comes this month on June 25, when the planet passes 5° south of an imaginary line between us and the Sun. In early July, it will reappear low in the morning sky.

Venus is an unmistakable beacon, now at its highest in the evening twilight. Venus never fails to delight with its powerful brilliance. It shines at magnitude –4.0 this month and is destined to get brighter still in the months to come.

Be sure to watch Venus as it joins Castor and Pollux in the constellation Gemini. The planet and two stars form a line with the young crescent Moon around June 12. Afterward, as Castor and Pollux sink into the Sun's glare, Venus glides on to meet the famous Beehive star cluster in the constellation Cancer. Binoculars are your best tool for viewing Venus as it passes the cluster on the evenings of June 19, 20, and 21.

Your telescope will reveal Venus as a yellowish disk measuring about 13.5" across. The planet is about three-quarters lit now as seen from Earth, but it will wane rapidly in phase — and grow larger in apparent size — over the coming months. The best months to see Venus through a telescope lie ahead, but you will enjoy the changes to come much more if you start watching the planet now.

When you have had an eyeful of the brightest planet, Venus, turn around and look high in the east for the second-brightest planet, **Jupiter**. It's so bright you can find it any time, but on June 18 and 19 it'll be the closest bright object to the Moon. Probably more people will peer at Jupiter this summer than ever before in anticipation of the upcoming collision of Jupiter with the fragmented Comet Shoemaker-Levy 9. What a grand spectacle it would be for someone watching from a moon of Jupiter! The planet will be spinning away mindlessly, while over 20 separate pieces of the comet slam into it, one by one, over a period of six days in mid-July. The comet fragments all will strike at the same latitude, but at different longitudes because Jupiter rotates.

When the collisions take place, the naked eye will detect nothing more astounding than Jupiter itself, a bold light in the heavens. Because a trained eye is much better at discerning subtle detail, now

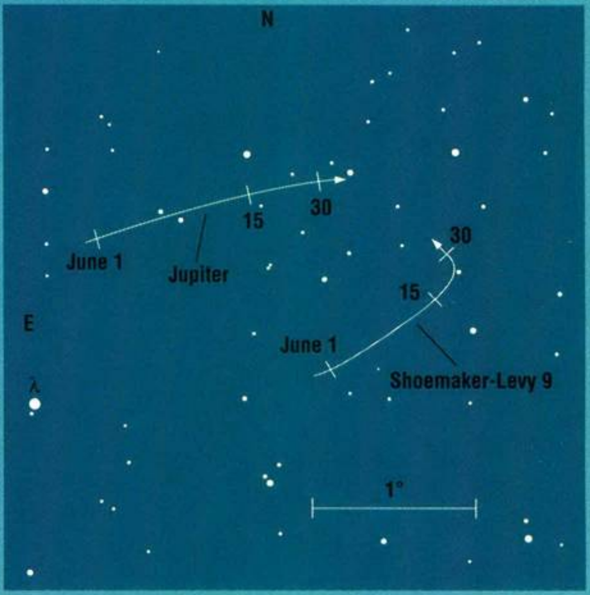
Keeping Tabs on Shoemaker-Levy 9

The tracks across the sky in June of Jupiter and Comet Shoemaker-Levy 9 hint at one of the big events of the year: July's collision between the comet and the planet. When Comet Shoemaker-Levy 9 passed close to Jupiter in 1992, tidal stresses broke it into more than 20 separate fragments, which are now all in separate but similar orbits. Next month Jupiter will finish the job it started in 1992, as all the Shoemaker-Levy fragments collide with the planet.

Although it's hard to know whether the effects of the comet's impact with Jupiter will be apparent to backyard observers this July, spotting the comet on the way to its demise will be very difficult. Some of the fun is in trying, however, so here are some tips for maximizing your chances. To spot the comet, you'll want a 12-inch or larger telescope with scrupulously clean optics, a dark observing site that provides steady seeing, and clear weather. Photographing the field conventionally or with a CCD camera will increase your odds of spotting it. To get the most out of viewing and photographing Jupiter, see "Jupiter's Magnificent Show" and "High-Impact Astrophotography" in the April 1994 issue.

The table at right gives you the position of the comet relative to Jupiter's position throughout June. To find the comet, first center Jupiter. To keep from spoiling your night vision, do this with the aperture stopped down to half an inch or less or while using a very dark neutral-density filter. Then offset to Shoemaker-Levy 9's position and remove the aperture mask or filter.

Choose an eyepiece that provides an exit pupil of about 2 millimeters. That much power will attenuate the background light below the level your eye can detect. Also use an eyepiece that has a small number of optical elements, such as a good Plössl or orthoscopic, to minimize the amount of light the elements absorb. Once you've done all that you may still not spot the comet, but at least you'll have given it your best shot.



COORDINATES FOR COMET SHOEMAKER-LEVY 9

On this date	Offsets from Jupiter West in R.A.	South in Dec.
June 1	5m53s	0°48.4'
June 7	5m23s	0°44.4'
June 13	4m50s	0°40.2'
June 9	4m16s	0°35.9'
June 25	3m40s	0°31.4'
July 1	3m02s	0°26.5'

is the time to begin scrutinizing this planet through the eyepiece of your telescope. Although the comet fragments will strike on the night side of the planet, powerful disturbances in Jupiter's atmosphere may rotate into our view. On the other hand, they may not. Not knowing exactly what will happen provides a key to the soul of the astronomer, a person who enjoys always pushing out into the unknown.

Jupiter shines this month at magnitude –2.3 while its disk appears 42" across in a telescope. The telescopic view of Jupiter reveals at least four large moons in orbit around the planet. Astronomers had predicted that we might witness the comet impacts indirectly, as light flashes off the surfaces of Io, Europa, Ganymede, and Callisto. But recent calculations indicate the brightenings of Jupiter's moons will be less dramatic. (See "Countdown to the Big Crash," page 40.)

Pluto, in Libra, is now just one month past opposition. It still shines at magnitude 13.7 and requires at least an 8-inch telescope to be seen. See "Take the Pluto Challenge" in last month's issue for details on finding this remote world.

Uranus and **Neptune** rise in late evening in early June and earlier as the month passes, as they move toward their July oppositions. Both appear in the constellation Sagittarius. Uranus shines at magnitude 5.7 while Neptune comes in at magnitude 7.9.

Saturn comes up in the after-midnight hours when the month begins, and you'll find it in the east about three-and-a-half hours after sunset by month's end. Saturn lies among the much-fainter background stars of Aquarius the Water Carrier, where it shines at magnitude 1.0.

In mid-June, Saturn's rings can be seen through small telescopes to have reached their least inclination for the year. The rings then are closed to only 4.9° from edge-on. Twice in every 30-year orbit of Saturn, the rings appear entirely edge-on. This will happen next in 1995. Now is a wonderful time for professional astronomers to look for thicker or brighter regions in the rings or to search for unconfirmed moons of Saturn. The rest of us will spend the coming year or two shaking our fists at the heavens and shouting, "Give us back our ringed planet!"

Mars occupies an inconspicuous place low in the east before dawn, and few people likely will notice it this month. The planet has not changed in brightness for months, shining at magnitude 1.2. □

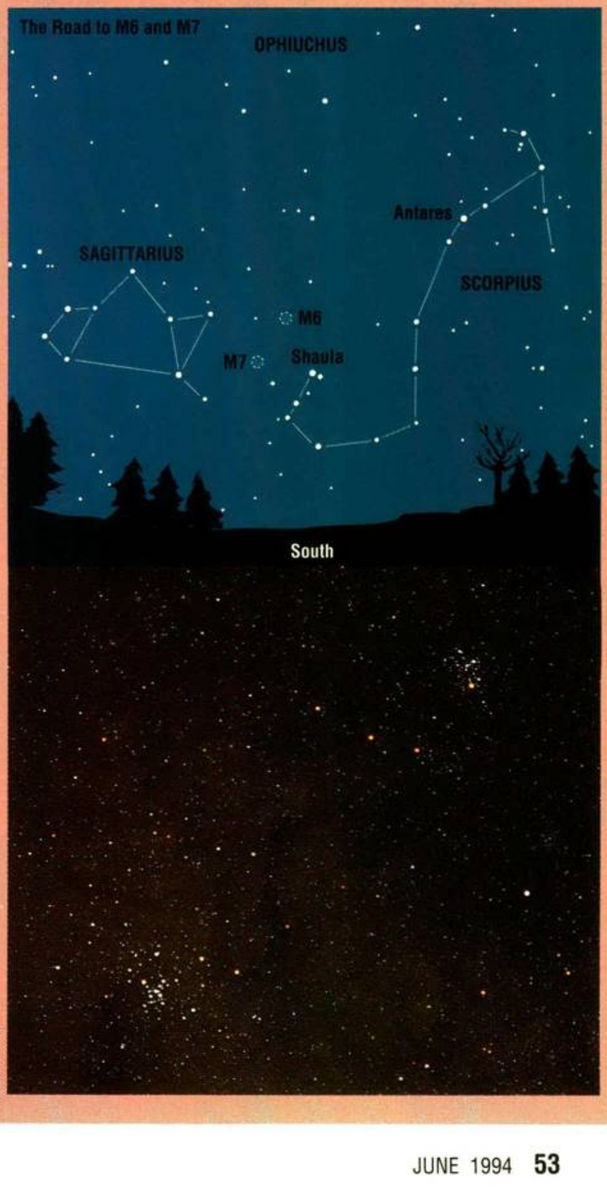
Deborah Byrd writes and produces the daily "Earth and Sky" radio series. Rick Shaffer is an engineer and writer living in Southern California.

A Pair of Bright Summer Clusters

Few sights in astronomy can equal the majesty of the summer Milky Way. From a dark site, the bright glow of our Galaxy's central hub and the milky-white band of the Galaxy's disk stand out against the inky background surrounding it. Although you need a dark sky to appreciate the full beauty of the Milky Way, light-polluted suburban skies still provide you with grand views of the brighter clusters and nebulae that populate our home Galaxy.

Nowhere is this more apparent than in the region between Scorpius and Sagittarius, which lies almost due south late on June evenings. This is where you'll find the bright star clusters M6 and M7. M7 is the brighter and larger of the two, appearing to the naked eye as a smudge of light some 4° northeast of Shaula, the star marking the Scorpion's stinger. The brightest star in M7 glows at magnitude 5.6, but the nearly 100 stars in the cluster combine to shine at magnitude 3.3. Your best view of this cluster will come in binoculars. Their light-gathering power will allow you to see dozens of individual stars, while their wide field of view lets you take in the entire cluster, which spans more than a degree.

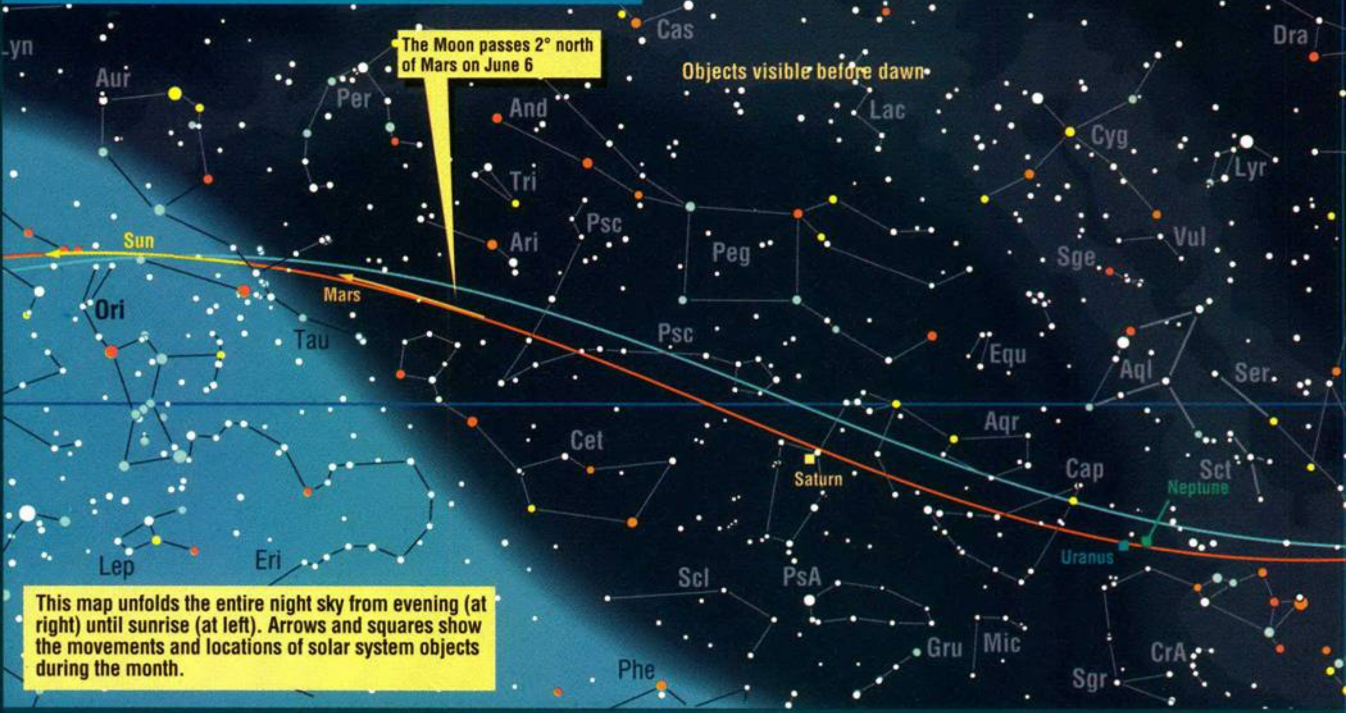
Head about 4° northwest of M7 and you'll come to another misty patch of light, the Butterfly Cluster (M6). Although it contains about the same number of stars as M7, M6 glows somewhat fainter at magnitude 4.2. (You may not discern this difference, however, because M7 is embedded in the bright background of the Sagittarius starcloud while M6 is surrounded by a lot of dark nebulae.) M6 lies significantly farther away than M7, some 2,000 light-years compared with 800 light-years for M7. That's also why the stars of M6 are packed much closer together, spanning just 1/4°. If you look carefully with binoculars, you may even find yourself agreeing with the many observers who see the shape of a butterfly's wing in the cluster's brighter stars.



Paul Burke

SKY ALMANAC

JUNE 1994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Uranus
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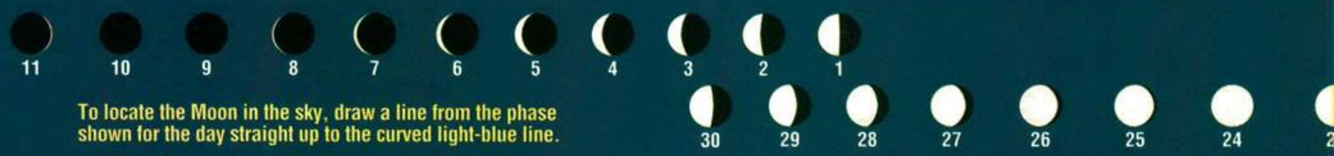
Gru
Mic
CrA
Sgr
Phe

The Moon passes 2° north of Mars on June 6

Objects visible before dawn

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.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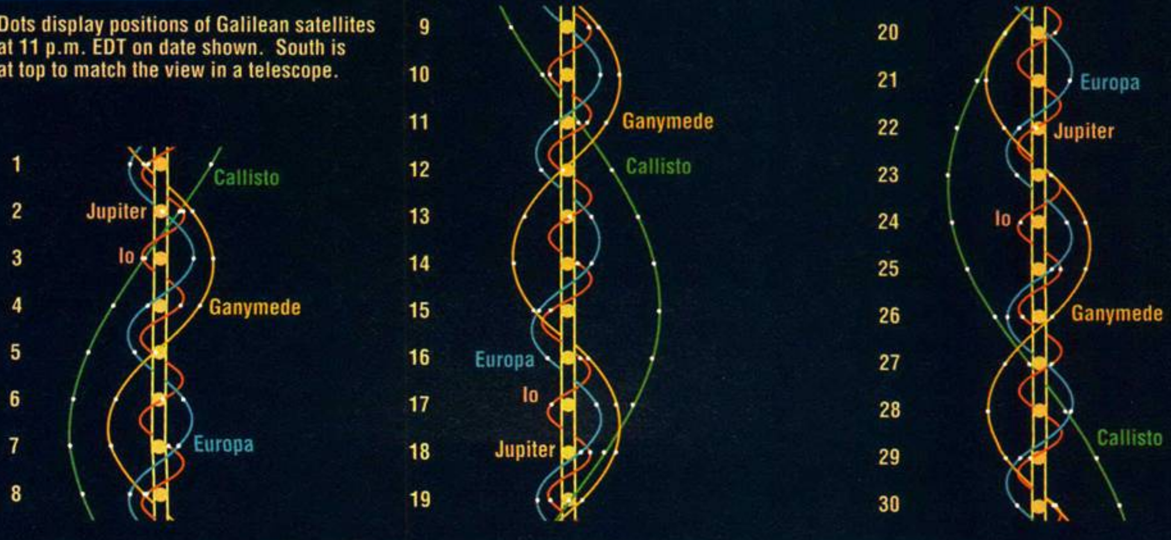
26
25
24

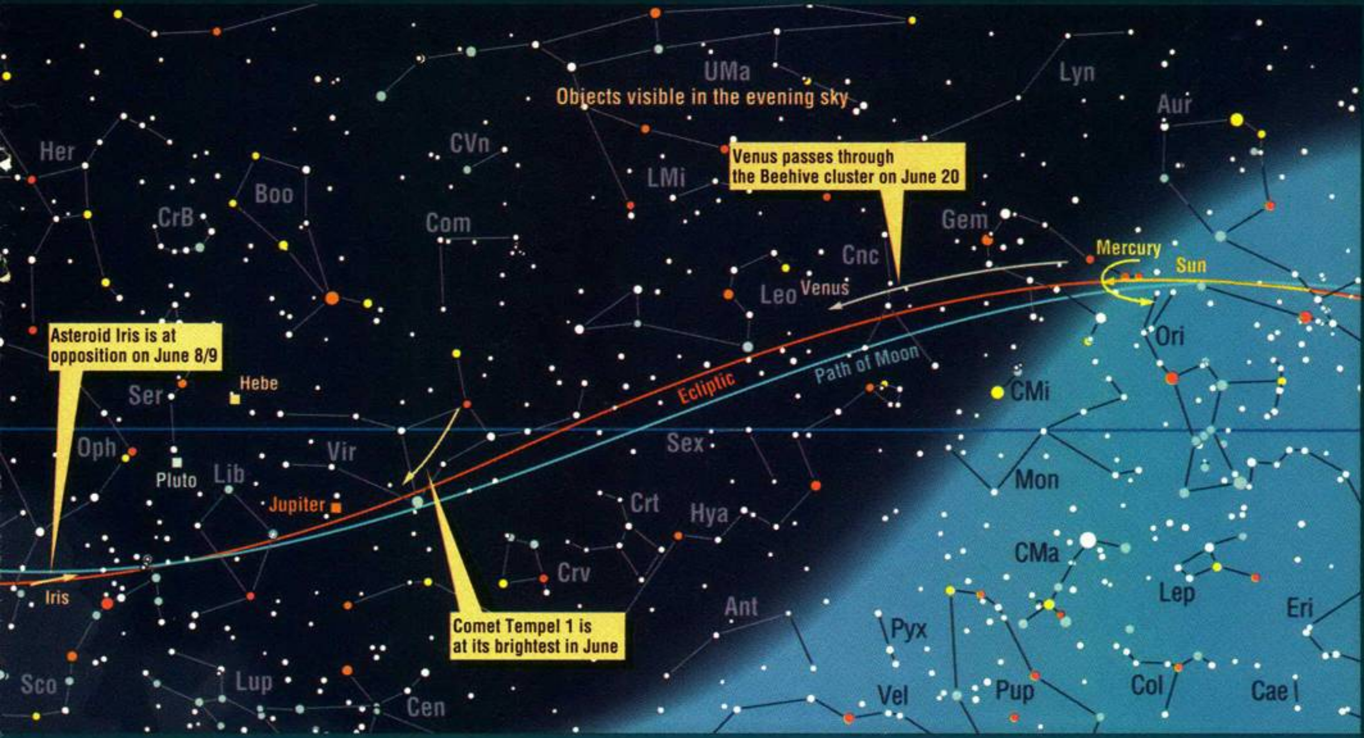
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

PLANETS	MERCURY	MERCURY	VENUS	MARS
Date	June 1	June 15	June 15	June 15
Magnitude	0.7	2.8	–4.0	1.2
Angular Size	8.5"	11.3"	13.6"	4.5"
Illumination	33%	8%	78%	95%
Distance (AU) from Earth	0.793	0.596	1.224	2.083
Distance (AU) from Sun	0.421	0.464	0.720	1.416
Right Ascension (2000.0)	6h14.7m	6h35.7m	8h09.3m	2h56.6m
Declination (2000.0)	25°00'	21°37'	22°08'	16°10'

JUPITER'S MOONS

Dots display positions of Galilean satellites at 11 p.m. EDT on date shown. South is at top to match the view in a telescope.

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CMi
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Sex
Pluto
Lib
Vir
Mon
Jupiter
Crt
Hya
CMa
Iris
Crv
Lep
Ant
Eri
Pyx
Sco
Lup
Cen
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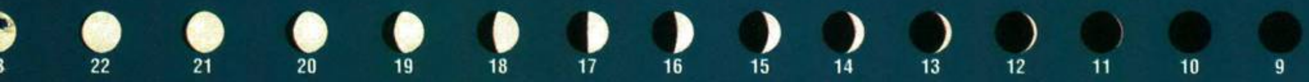
Objects visible in the evening sky

Venus passes through the Beehive cluster on June 20

Asteroid Iris is at opposition on June 8/9

Comet Tempel 1 is at its brightest in June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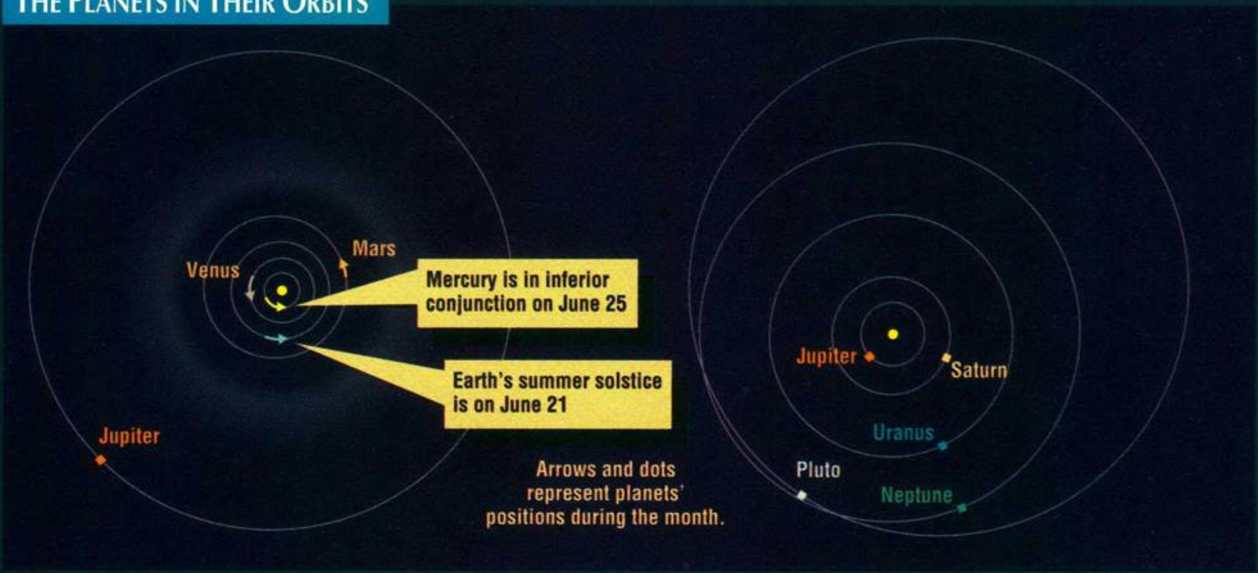
JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
June 15	June 15	June 15	June 15	June 15
–2.3	1.0	5.7	7.9	13.7
41.9"	17.4"	3.7"	2.3"	0.1"
100%	100%	100%	100%	100%
4.696	9.485	18.790	29.286	28.909
5.423	9.736	19.660	30.178	29.784
14h13.7m	22h57.9m	19h50.9m	19h38.0m	15h48.2m
–12°05'	–8°30'	–21°32'	–20°54'	–5°19'

THE PLANETS IN THEIR ORBITS


Venus
Mars
Jupiter
Jupiter
Saturn
Uranus
Pluto
Neptune

Mercury is in inferior conjunction on June 25

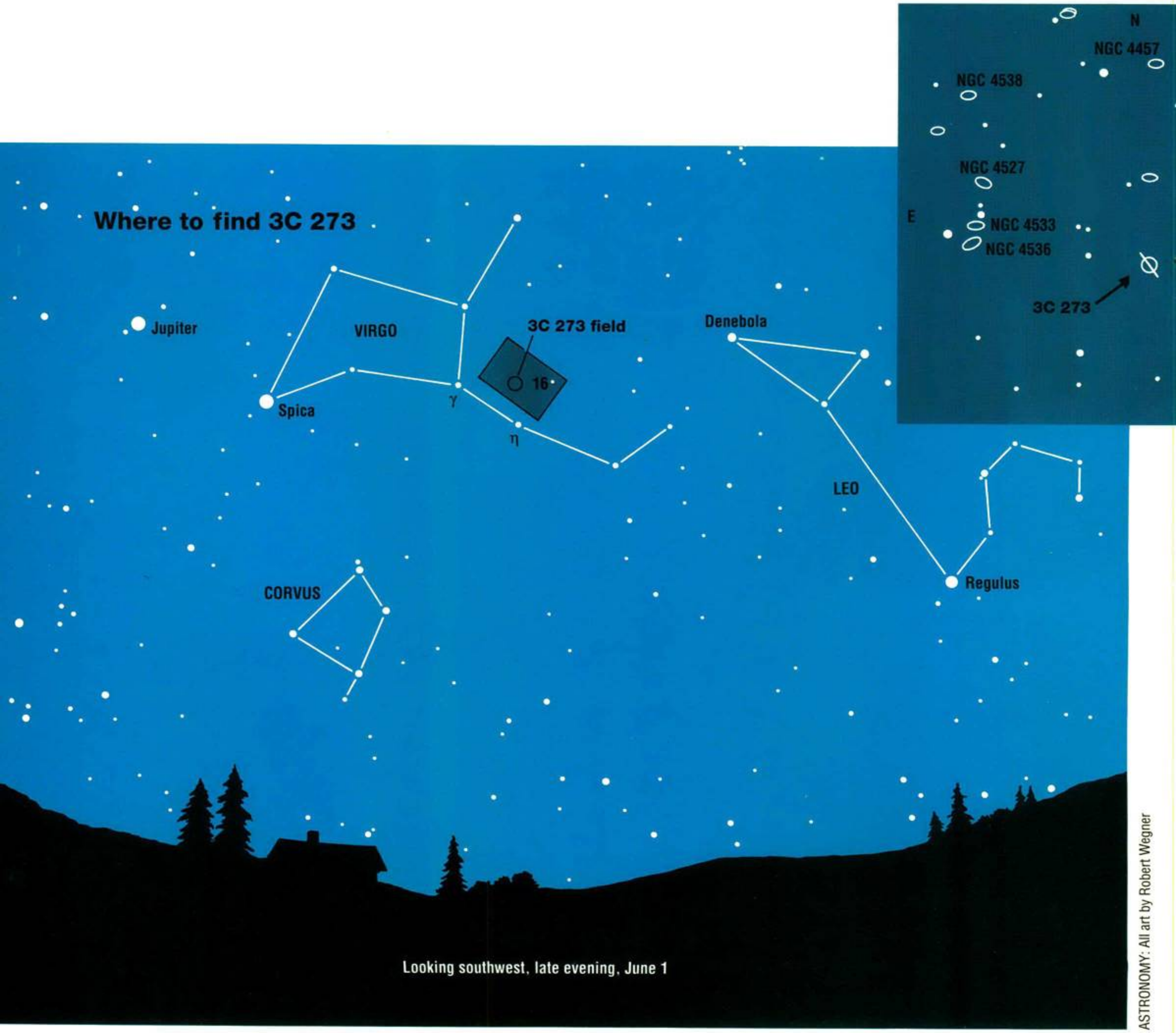
Earth's summer solstice is on June 21

Arrows and dots represent planets' positions during the month.

Tracking down a Quasar

Observe to the limits of your telescope by spotting these distant, infant galaxies billions of light-years from home.

by Phil Harrington


Where to find 3C 273
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VIRGO
Spica
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3C 273 field
16
Denebola
LEO
Regulus
CORVUS
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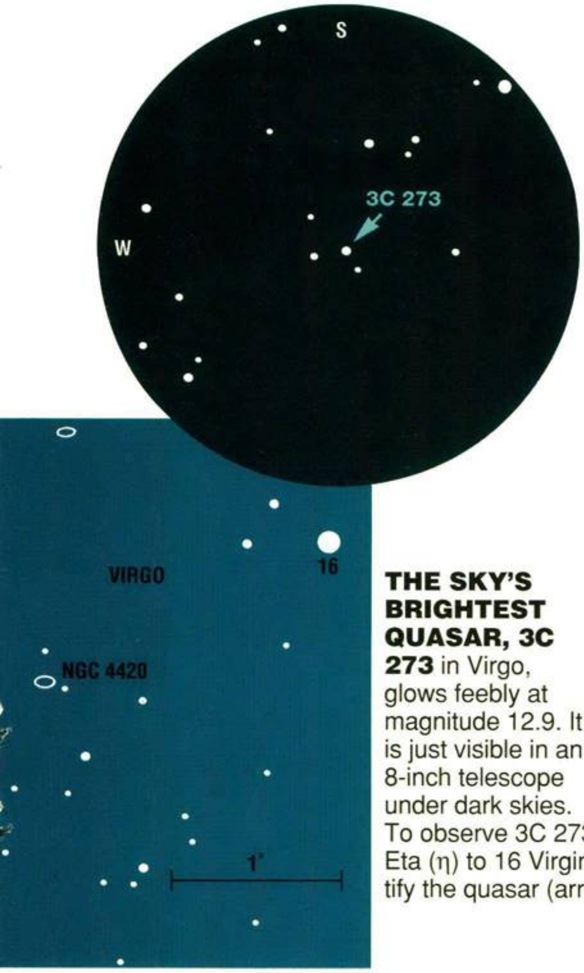
NGC 4538
NGC 4527
NGC 4533
NGC 4536
3C 273

Looking southwest, late evening, June 1

ASTRONOMY: All art by Robert Wegner



Palomar Observatory

THE SKY'S BRIGHTEST QUASAR, 3C 273 in Virgo, glows feebly at magnitude 12.9. It is just visible in an 8-inch telescope under dark skies. To observe 3C 273, face southwest on a June evening and locate Virgo. Star hop from Eta (η) to 16 Virginis, and aim your scope 2½° southeast. Use the chart above to identify the quasar (arrow).

It happened long ago and far away, in an obscure corner of the universe, when the stuff of the cosmos was all very young. There, the blazing center of a young galaxy bathed the space around it with intense radiation. The clock had ticked a few billion years past creation. There were no witnesses, no living creatures to record the brilliant genesis of the baby galaxy.

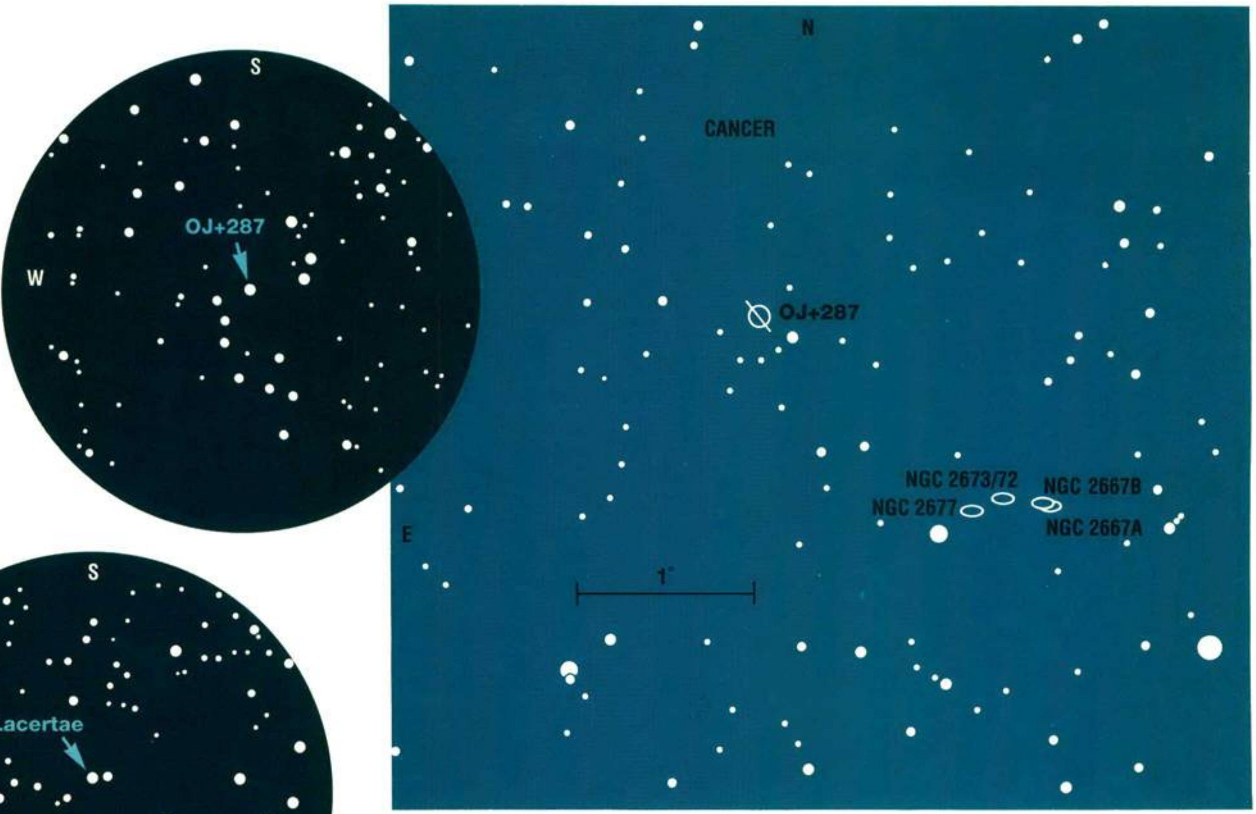
Billions of years later, in 1963, astronomers looked back in time and recognized a quasar. It had been a long time coming. In the late 1960s astronomers also identified a second quasarlike object called a BL Lacertae object, named for the prototype, BL Lacertae. (These objects resemble quasars but have spectra without bright or dark features as quasars do.) After several years of debate, astronomers have determined that quasars and BL Lacertae objects are the highly energetic, active centers of young galaxies. As these galaxies age, they settle down into a less violent outpouring of energy and resemble the Milky Way and the Andromeda Galaxy — like galaxies we see nearby.

Although no one but professional astronomers observed quasars in the days following the discoveries, now you too can observe them. The brightest one is still rather faint, glowing weakly at magnitude 12.9. To see it you'll need a dark, moonless sky and a telescope of at least 8 inches aperture. Several other quasars and BL Lacertae objects glow at 14th to 16th magnitude. To see them you'll need a 12-inch or 14-inch scope under dark skies. You'll also need to use finder charts patiently (like those provided here) when out under the stars. To track down objects mentioned but not included in these finder charts, consult *Uranometria 2000.0* by Wil Tirion, Barry Rappaport, and George Lovi, and *A Handbook of Quasistellar and BL Lacertae Objects* by Eric R. Craine.

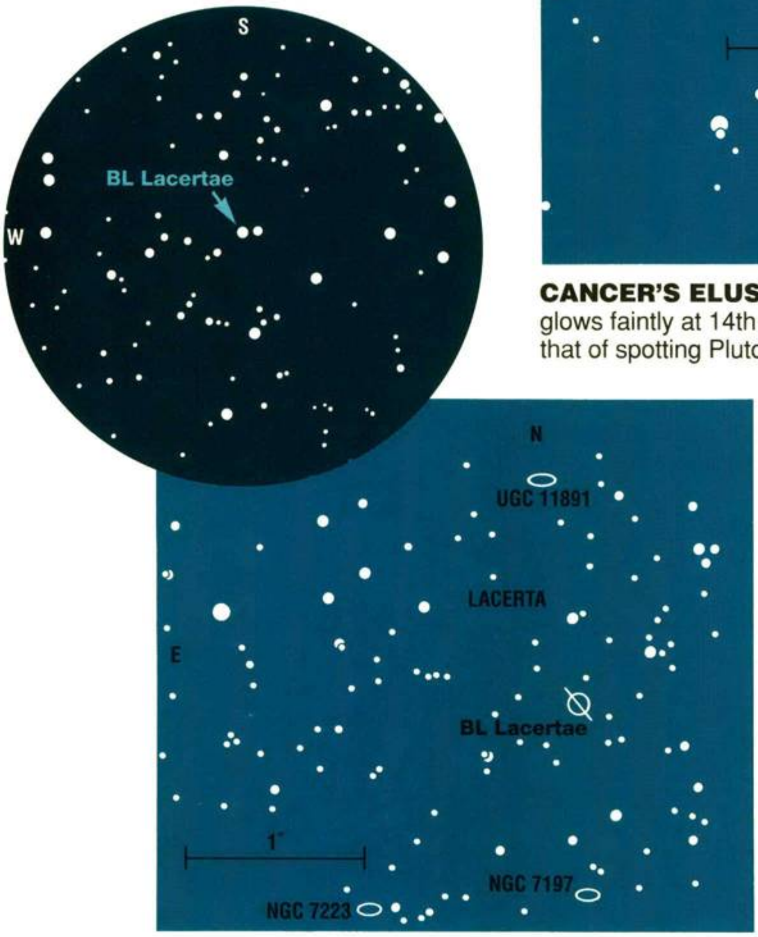
Nearby galaxies look fuzzy, distant ones like faint stars. That's because we see only the brilliant tiny centers of these distant galaxies across the void of the universe — the nebulous collar of light that surrounds the center is dim. So tracking down a quasar is much like going after a faint star. It's an exercise of the mind as much as one of using a telescope. The thrill lies in knowing what you're looking at.

On our field trip we'll track four quasars and six BL Lacertae objects in order of their increasing distance from us. This means taking a trip back in time through the ages. Pack up your eyepieces, dark-adapt your eyes, and get ready to head off into the deep dark corners of the universe.

Our first stop, **Markarian 421** (11h4m27s, +38°12'32", epoch 2000 coordinates), offers a magnitude 13.5 BL Lacertae object located a mere 390 million light-years away. (Distances here are based on a value for the Hubble constant of 23 km/sec/Mly.) To



CANCER'S ELUSIVE OJ+287 varies irregularly in brightness but typically glows faintly at 14th magnitude. This makes it a challenge almost identical to that of spotting Pluto, which requires a 10-inch scope.



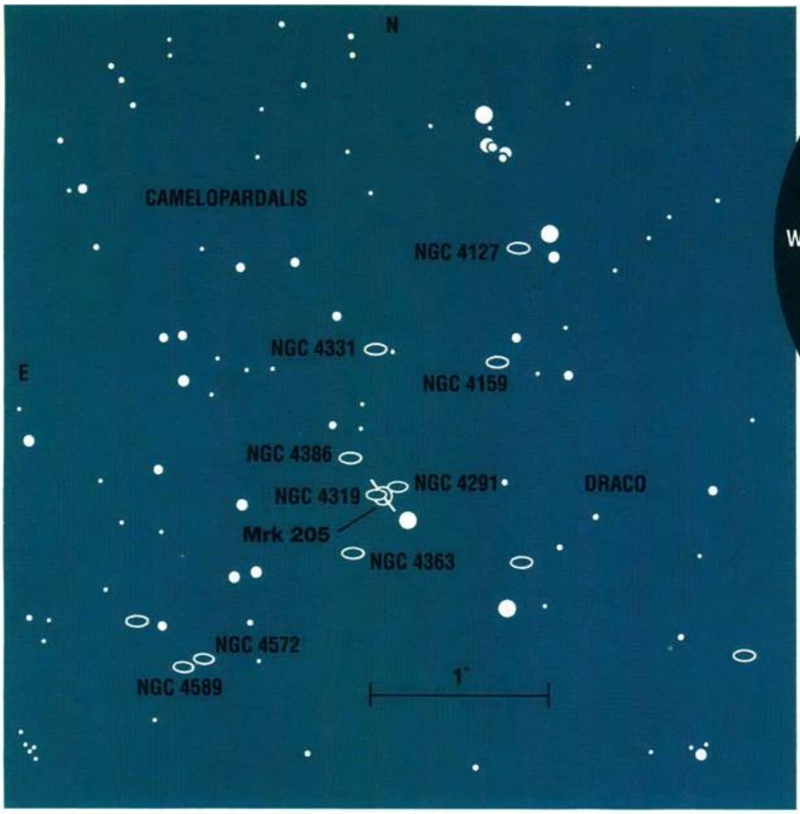
BL LACERTAE resembles a quasar but shows weaker emission features in its spectrum. The 15th-magnitude "star" lies among a rich field in the dazzling summer Milky Way.

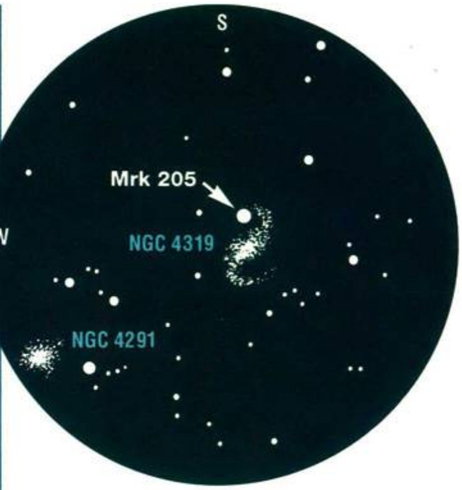
find Markarian 421, start at the 6th-magnitude star 51 Ursae Majoris. Switch to a high magnification and aim your scope slightly southwest of the bright star. Markarian 421 lies just a few arcminutes away from the star. Move the star just outside your high-power field to minimize glare and spot the BL Lacertae object. Viewed with the largest telescopes, this object shows a diffuse collar of fuzz. It has varied in brightness by several magnitudes.

Taking a step out to 425 million light-years away, we can locate **Markarian 501** (16h53m52s, +39°45'37"), a BL Lacertae object found just north of the "keystone" asterism in Hercules. This object glows faintly at magnitude 13.9 and, like most quasars and BL Lacertae objects, varies irregularly in brightness. To locate it, aim your scope toward the 4th-magnitude star Eta (η) Herculis. Move the scope 3° northeast to find the proper field.

Finding the BL Lacertae object **AP Librae** (15h17m42s, –24°22'19") will carry you out to a distance of 600 million light-years. This starlike point glows elusively at magnitude 14.8, making it a challenge in scopes less than 12-inches in aperture. Zero in on the field of AP Librae by starting at 3rd-magnitude Sigma (σ) Librae. Shifting 4° east brings you to the correct area. This object's designation resulted from astronomers' originally believing it was a variable star; indeed, the object has varied between magnitudes 14.5 and 16.4. The object has a fuzzy glow surrounding it measuring only 20" across, and this is probably not visible in backyard telescopes.

Another BL Lacertae object, **BL Lacertae** (22h2m43s, +42°16'40") itself, lies an impressive 840 million light-years away. Glowing at magnitude 14.7, this object requires the same telescope firepower as that of AP Librae. Find BL Lacertae by aiming your scope at the 6th-magnitude double star 77 Cygni. From there, move 1° north and 3° east. BL Lacertae has shown a significant range of variability, from magnitude 12.5 to 16.5. At the same distance of 840 million light-years, in the direction of the constellation Draco, you may find our first bonafide quasar, **Markarian 205** (12h21m44s, +75°18'37"). This magnitude 14.5 object is rather easy to find because it lies 42" southeast of the 12th-magni-





THE QUASAR-GALAXY PAIR
Markarian 205 and NGC 4319 in Draco requires a 12-inch or larger scope to be seen. Though the narrow separation is almost certainly coincidence, some astronomers believe the objects are physically connected.

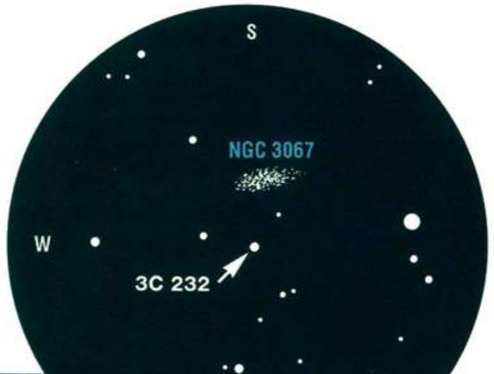
tude galaxy NGC 4319. The galaxy is a foreground object a stone's throw (80 million light-years) away.

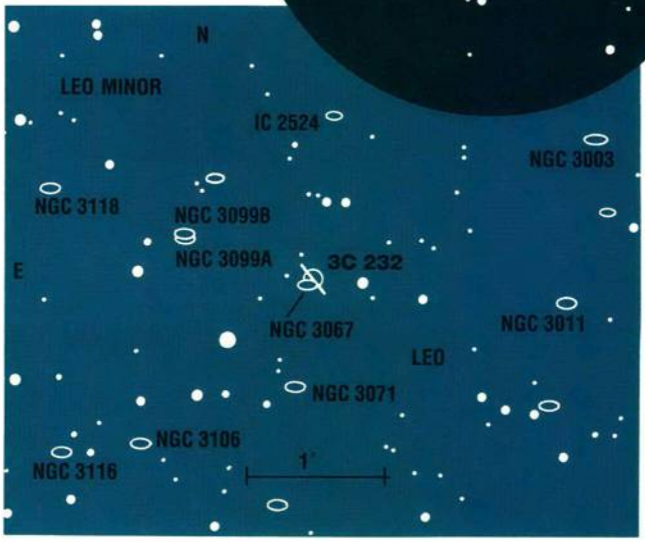
As we pass the milestone distance of 1 billion light-years, we encounter at 1.7 billion light-years' distance the first known quasar, **3C 273** (12h29m7s, +2°3'7"), the one found back in 1963. The brightest of all quasars, 3C 273 can be found with an 8-inch scope by aiming the scope toward 4th-magnitude Eta (η) Virginis. Next, move 4° north to the 6th-magnitude star 16 Virginis. Hone in on the quasar by aiming 2½° southeast of this star.

Owners of large scopes may wish to go after two more distant BL Lacertae objects, **OJ+287** (8h54m49s, +20°6'32") and **0735+178** (7h38m7s, +17°42'21"). Located in the star-poor constellation Cancer, OJ+287 lies 2.9 billion light-years away and glows feebly at magnitude 14.0. This object has varied in brightness between magnitudes 13.7 and 16.0. Conversely, 0735+178, with its distance of 3.6 billion light-years and magnitude of 14.9, resides in the star-rich Milky Way of Gemini. This object has varied between magnitudes 14.5 and 16.7.

Those who seek a challenge may wish to go for a long distance record. Two quasars tantalize large scope owners: **3C 232** (9h58m21s, +32°24'2") and **0405–123** (4h7m48s, –12°11'37"). In similar fashion to Markarian 205 and NGC 4319, 3C 232, a magnitude 15.8 quasar, lies a few arcminutes north of the galaxy NGC 3067 in Leo. The objects are separated in space by a gulf of more than 4 billion light-years, however. The quasar lies 4.1 billion light-years away while the galaxy is practically a neighbor at 60 million light-years' distance. Moving out to a distance of 4.3 billion light-years, we come to the quasar 0405–123 in Eridanus. This magnitude 14.8 object is faint enough to give you problems finding it even as you marvel over the fact that its light began its journey across the universe when Earth was in its earliest stages as a planet.

AN EXTREME CHALLENGE
comes with spotting quasar 3C 232, which lies a few arcminutes north of the brighter galaxy NGC 3067 in Leo.





Quasars and BL Lacertae objects provide a window into the distant universe for someone equipped with a moderate-sized telescope. They challenge our telescopes and our eyes. But mostly, they allow us to dream by looking back in time as we look out through space. ☐

Phil Harrington frequently contributes to ASTRONOMY. *His last article was "Running a Celestial Marathon" (March 1994).*

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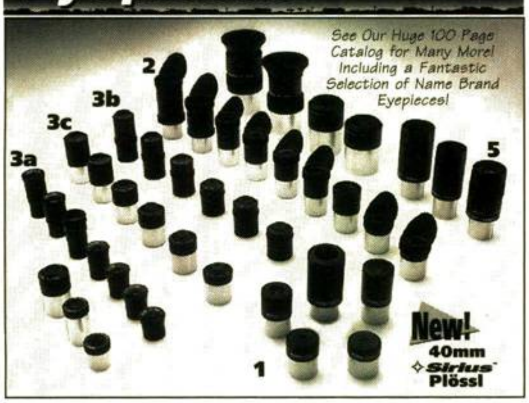
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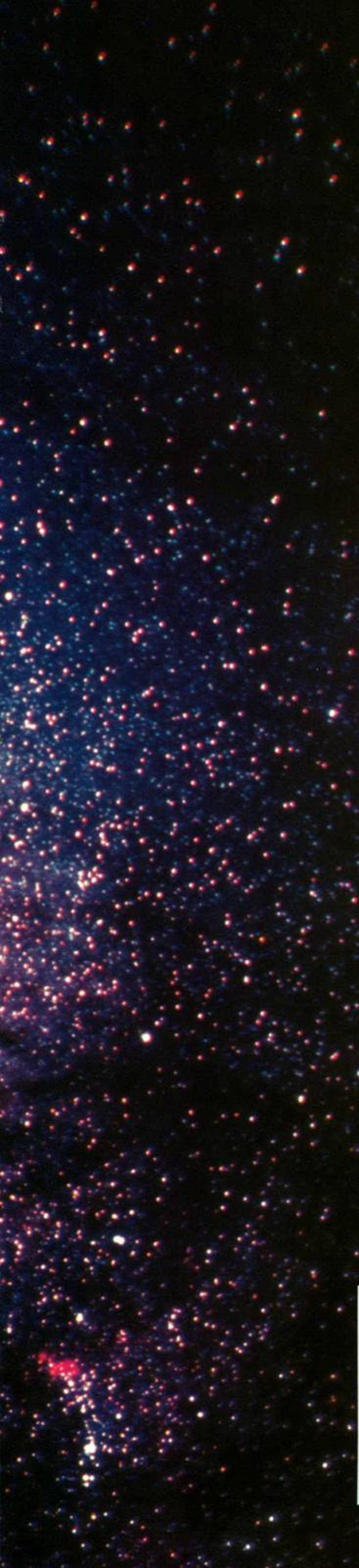
Glittering Realms of the Summer Milky Way

The arch of our Galaxy's center rises each evening, offering wondrous views in Cygnus, Aquila, and Sagittarius.

by David J. Eicher

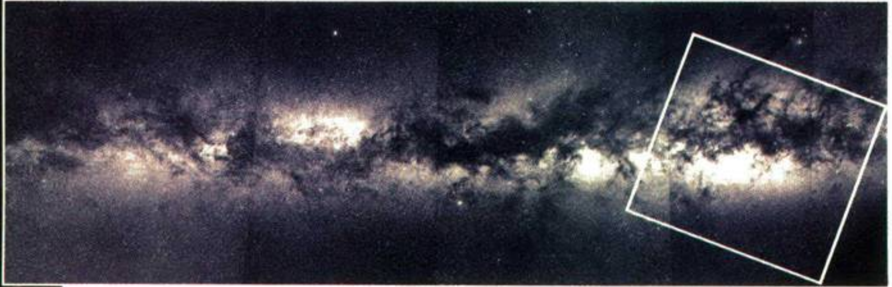
We owe a lot to the Milky Way: Its disk, 100,000 light-years long provides most of the glowing matter that we see around us. In *Paradise Lost,* John Milton described it as "A broad and ample road, whose dust is gold . . . Powder'd with stars." But for many of us, it's paradise found because armed with binoculars, telescopes, and even our eyes alone, we can travel that gold-dusted road.

On warm summer nights, the arch of the Milky Way passes over our heads just after midnight. In this starry band, crowded with contellations and deep-sky objects, we see three distinct areas you can explore. Straight overhead flies Cygnus the Swan, marked by a bright cross-shaped pattern of stars. Cygnus holds some of the Galaxy's most striking examples of emission nebulae, clouds of hydrogen gas slowly squeezing into myriad newborn stars. Follow the band of the Milky Way south to see stately, V-shaped Aquila the Eagle, home of a splendid collection of planetary nebulae, the expanding shells cast off by dying stars. Southward your gaze moves until reaching Sagittarius the Archer, the teapot-shaped star group that marks the direction of our Galaxy's center. Sagittarius is a paradise filled with delights

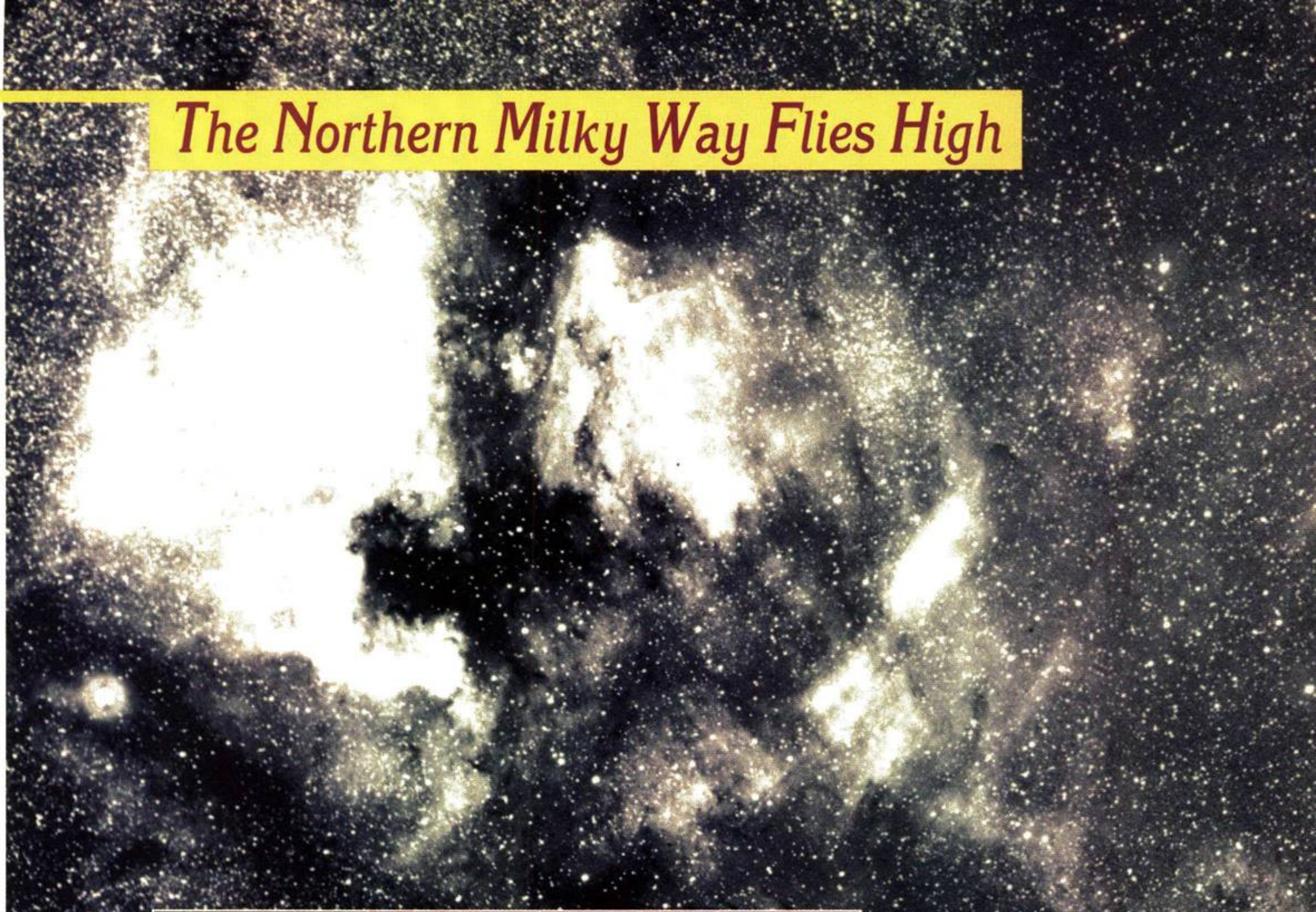


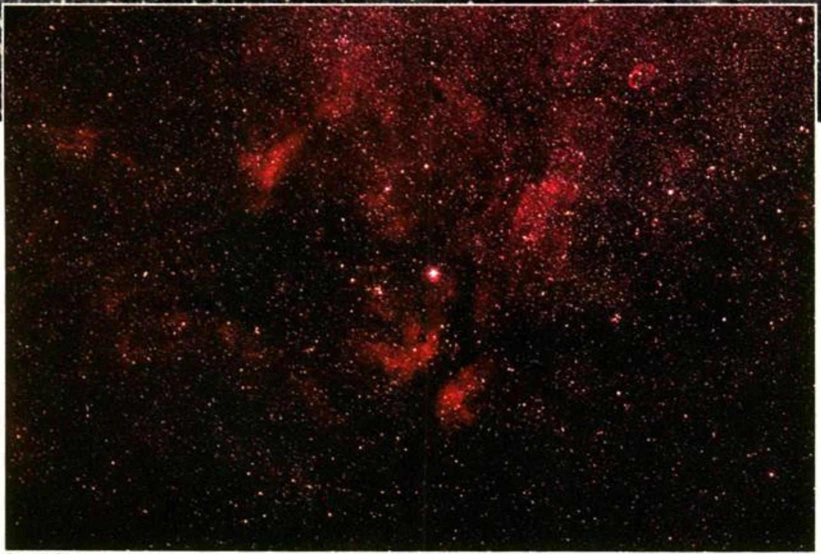
Ronald E. Royer

THE HEART OF THE GALAXY glides across the sky masked by the constellation Sagittarius, visible in summer's evening sky. The box below outlines this area in a mosaic created at Palomar Observatory showing the Milky Way from Cassiopeia (left) to Centaurus (right).



The Northern Milky Way Flies High





Gerald Rhemann

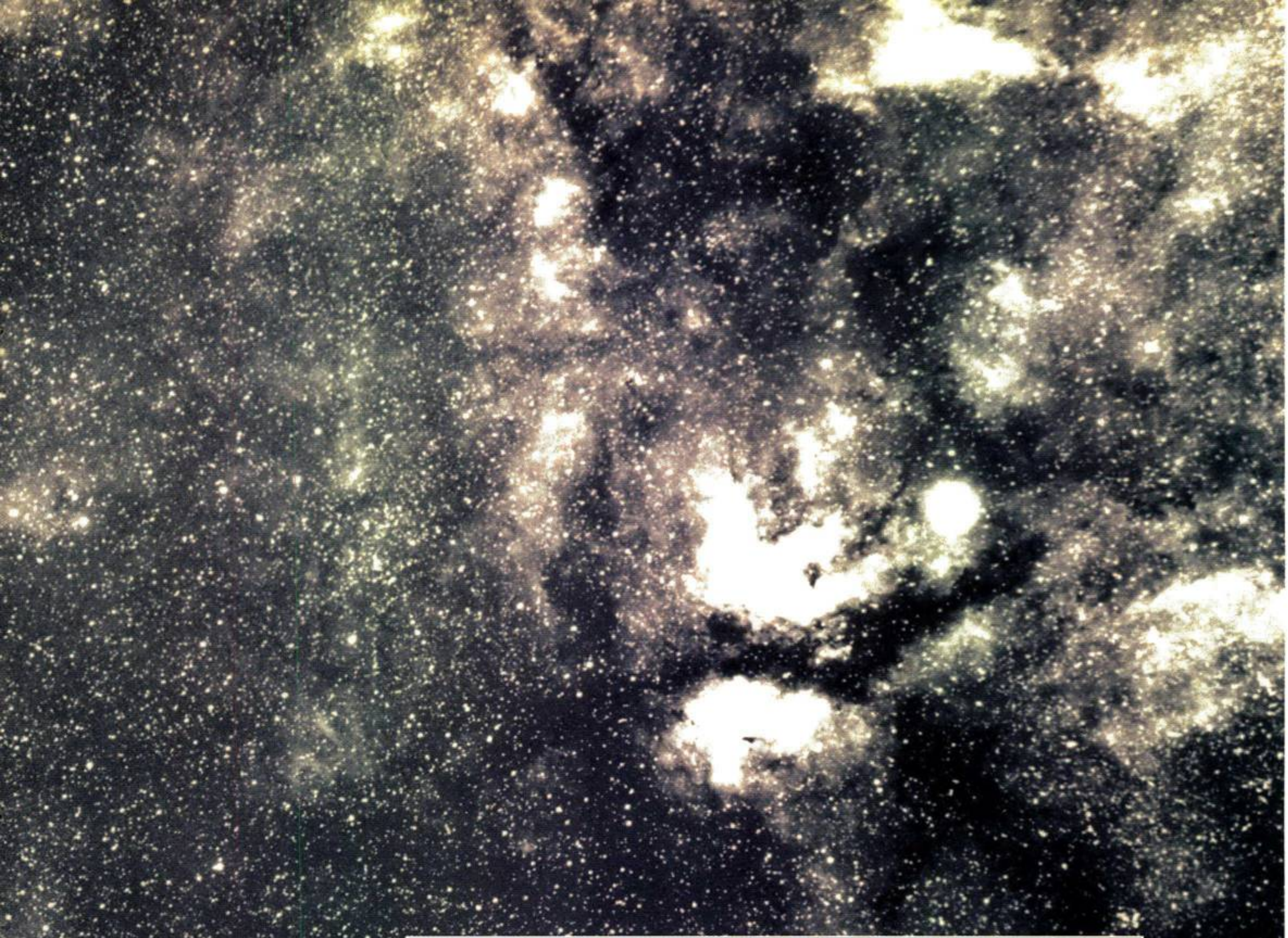
CYGNUS THE SWAN offers a flock of nebulae, from the North America and Pelican nebulae (left above) to the myriad nebulosities surrounding the bright star Gamma Cygni (right above).

RUDDY HUES characterize the nebulae collectively catalogued as IC 1318 that surround the naked-eye beacon Gamma Cygni (center of image). Such emission nebulae will turn out new stars from old gas, creating a stellar nursery.

for sky observers, an area richly studded with bright star clusters and nebulae.

To begin your walk on the golden road, chose the area that offers what you want to see. If you're up for tracking down the mellow light of emission nebulae, trek out on a dark night when Cygnus lies straight up and take along a pair of binoculars. Shift your gaze 3° east-southeast of Deneb, Cygnus' brightest star, and you'll be looking at the North America Nebula (NGC 7000), one of the brightest emission nebulae in the sky. Glowing with the light of a 1st-magnitude star spread over as much sky as sixteen Full Moons, the North America Nebula stands out to the naked eye as a prominent glow under a dark, moonless sky. But binoculars show it as a bright, fuzzy, oval glow bounded by sharply defined dark nebulae.

Just west of the North America Nebula you may see the much fainter Pelican Nebula (IC 5067-70), visible faintly in a wide-field telescope on the very darkest nights. (The origins of the sobriquets for these nebulae become clear when you examine a photograph of them like the one above.) A complex of similarly challenging nebulae girdles the star Gamma Cygni, the central star in Cygnus' cross.

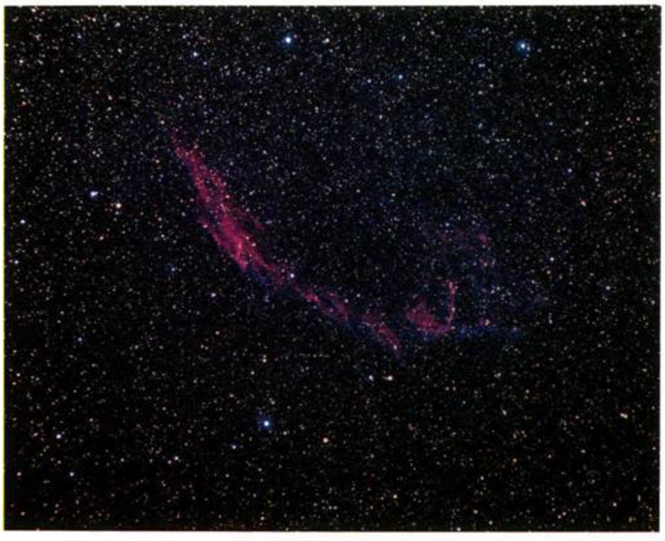


Michael Stecker

Many of these nebulae share the label IC 1318, and most require a dark night and an 8-inch scope to be seen.

While the North America and Pelican nebulae are composed of gas slowly assembling itself into newborn stars, Cygnus also holds nebulae from the other end of the stellar life cycle. Some 14° south of Deneb lies the 4th-magnitude double star 52 Cygni. This pretty star floats majestically in front of one component of the Veil Nebula, a dimly glowing supernova remnant. These remains of a stellar explosion occurring some 20,000 years ago are slowly floating into the winds of the Galaxy, which will ultimately disperse them. The glowing arc that appears to cross paths with 52 Cygni, NGC 6960, shows itself to a 6-inch telescope on a dark night. The same holds true for the slightly brighter component, NGC 6992-5, located 2° to the east-northeast.

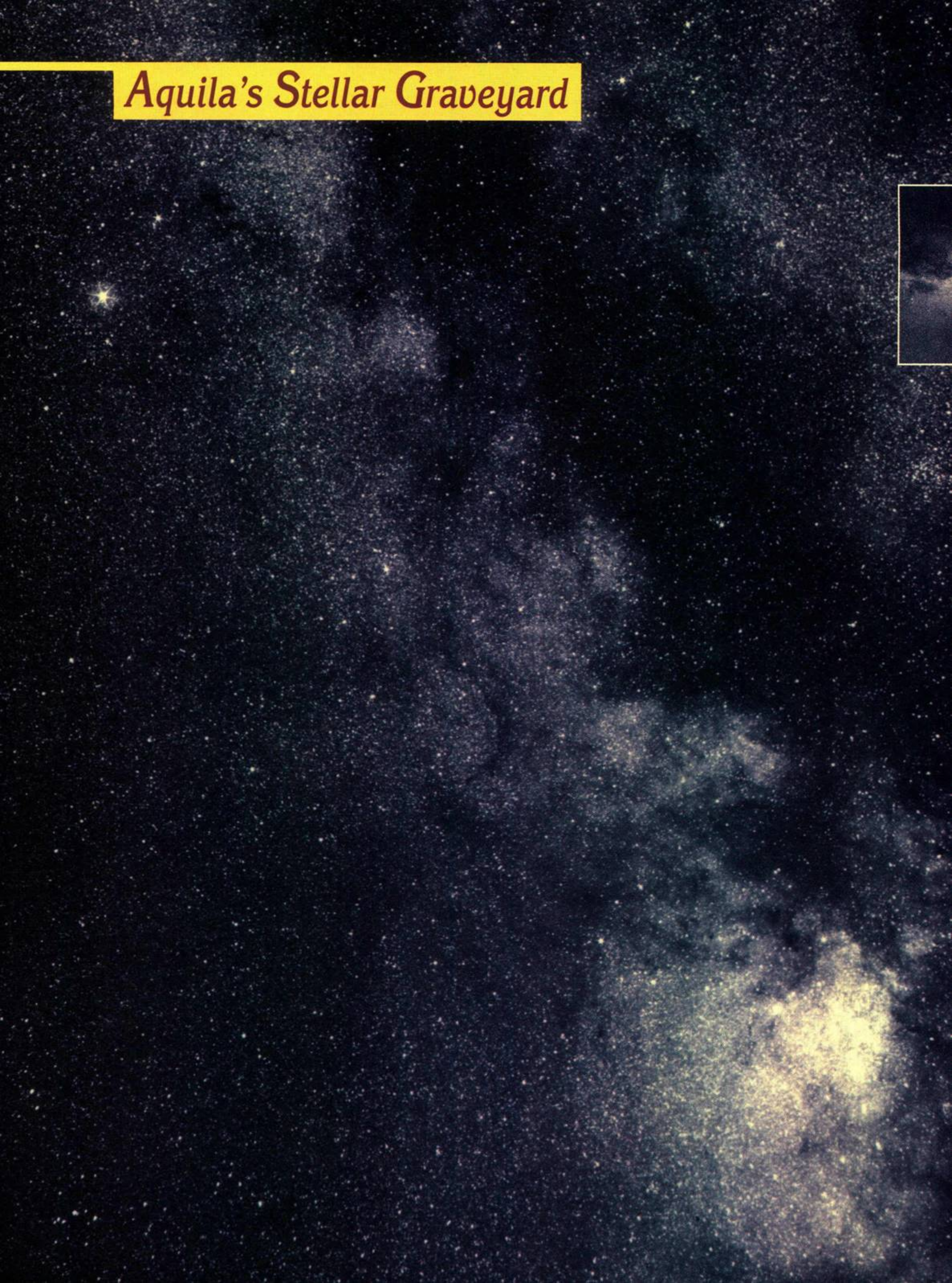
Stars do not die by supernova alone — only very



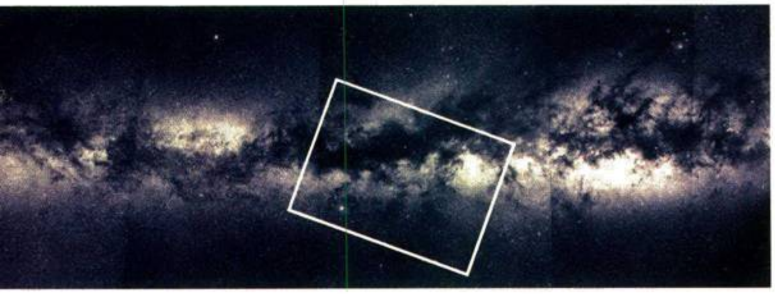
LIKE TWISTED STRANDS OF ROPE, the Veil Nebula's complex structure can be seen in a 6-inch telescope on a dark, clear night. The nebula consists of debris from an ancient supernova explosion.

Jason Ware

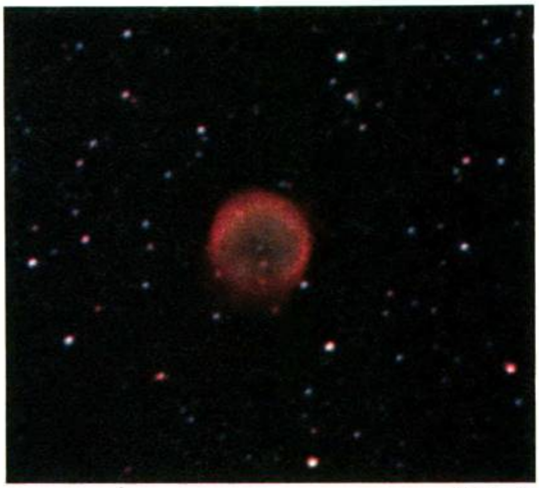
Aquila's Stellar Graveyard



LOST IN STARCLOUDS, the V-shaped constellation Aquila (far left) seems overwhelmed in this long-exposure photo. The constellation's brightest star, Altair, remains visible at left center. Aquila contains a spectacular collection of planetary nebulae, the remnants of dying stars, two dozen of which are visible with small telescopes.



Martin C. Germano



Jack Newton

THE GHOST OF A ONCE HEALTHY SUN, planetary nebula NGC 6781 shows us the endgame of life for most stars. The shell of gas will slowly expand until swept asunder by the winds of the Galaxy's disk.

massive ones do. Most stars slowly expire by puffing away their material until a bald, hot sun sits at their center and cooks the gas into a glowing shell. Such an animal is called a planetary nebula, named for its telescopic resemblance to a planet.

Aquila holds a first-rate collection of these planetaries, the best being the ghostly disk of NGC 6781. This glow lies 4° north-northwest of Delta (δ) Aquilae, the 3rd-magnitude star marking the upper right of Aquila's distinctive V shape. You'll see the faint circular fuzz of NGC 6781 by using a 4-inch scope on the darkest of nights. This nebula's 15th-magnitude central star, the star that launched the shell into being, is a telescopic challenge. A neighbor, planetary nebula NGC 6804, lies 4° to the northeast. This object sports a brighter central star and a disk visible in a 3-inch scope on a good night.

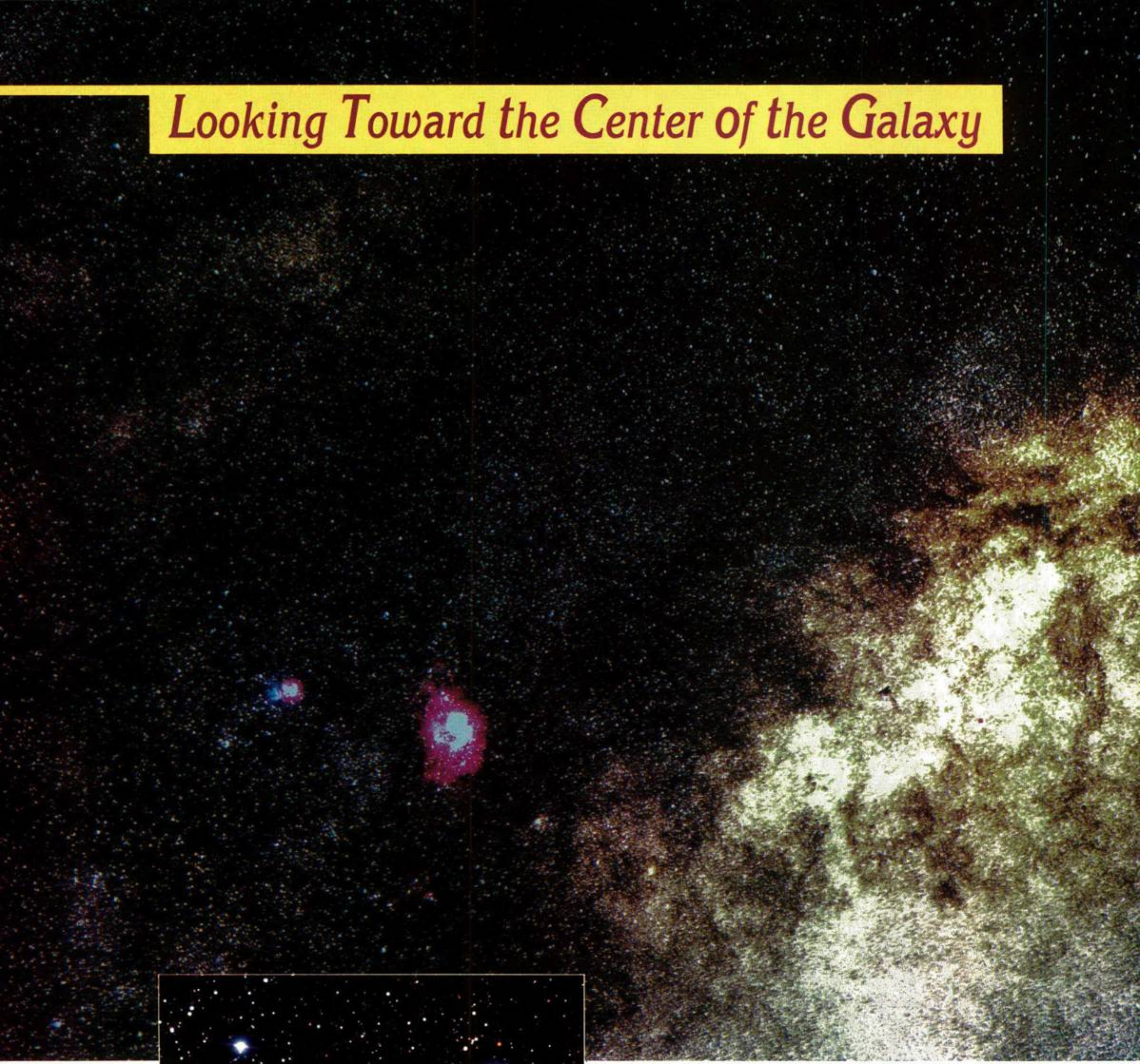
Planetary nebulae, emission nebulae, supernova remnants, and other types of galactic creatures fill every corner of Sagittarius. The most prominent must be the Lagoon Nebula (M8), a glowing star factory visible to the naked eye as a fuzzy "star." This gas cloud can be found 5½° north of Gamma (γ) Sagittarii, the "spout" in the constellation's teapot asterism. The hydrogen gas in such emission nebulae glows by fluorescence — it's excited into luminescence by the hot stars embedded within it. A small telescope shows these hot stars in the Lagoon Nebula, collectively termed open star cluster NGC 6530, visible in the eastern portion of the nebula. Large backyard scopes will show a much fainter nebula, NGC 6559, located 1° east of the Lagoon.

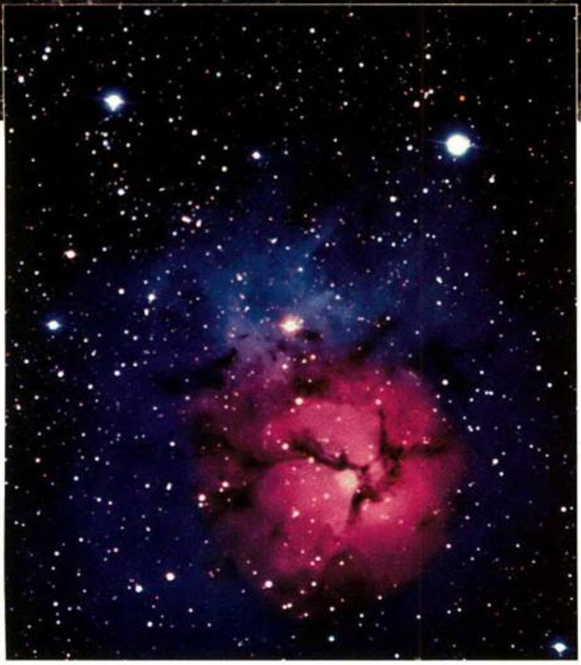
Unlike the Lagoon and NGC 6559, the Trifid Nebula (M20) — found just 1° north of the Lagoon — glows from both emission (red

A BRIGHT CENTRAL STAR (center of image, right) marks the position of planetary nebula NGC 6804. The ring of material surrounding it, visible in small scopes, is the most recent shell shaken off by the star. Its larger, fainter shell marks the remnant of an earlier episode of mass loss.

Kim Zussman

Looking Toward the Center of the Galaxy





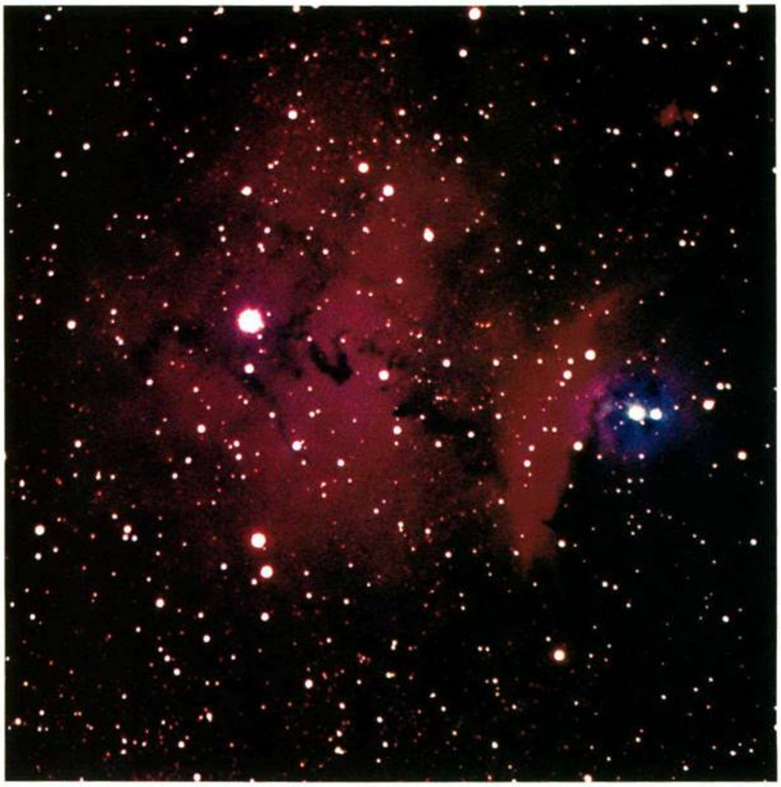
Bill and Sally Fletcher

THE CENTER OF THE MILKY WAY, hidden by vast shrouds of dust and the blur of light from uncountable stars, lies behind a point near the top center of the photo above. Two huge star factories, the Lagoon and Trifid nebulae (left), lie about one-sixth of the way from Earth to the galactic center.

THE TRIFID NEBULA consists of light that glows by emission (red) and by reflection (blue). Excited by the hot stars embedded in it, the reddish gas glows in similar fashion to a fluorescent light. The bluish dust, on the other hand, consists of nonluminous particles reflecting light from near the nebula.

Ronald Royer and Steven Padilla

DARK NEBULAE OBSCURE OUR VIEW of the galactic center. Consisting of tiny soot-like particles, these clouds block light from objects behind them. A small, twisting dark nebula appears highlighted against NGC 6559, which glows diffusely in the background.

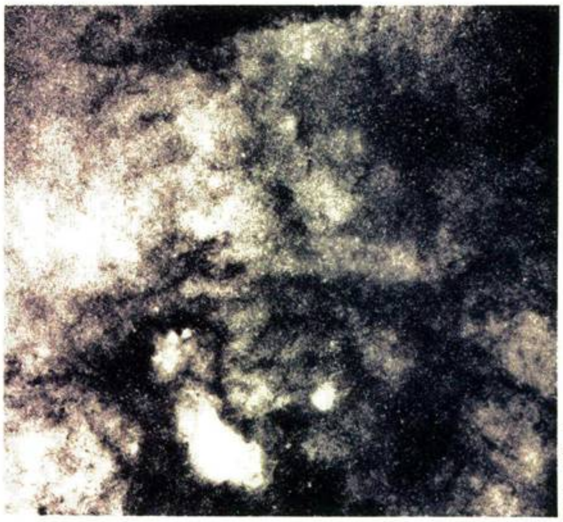


George Greaney and Mike Newton

A DEEP EXPOSURE of central Sagittarius shows the thick starclouds that obscure our view of the Milky Way's core. The Lagoon and Trifid nebulae (bottom) appear as overexposed white blobs; interstices of dark nebulae wind through luminous sheets of starlight.

in photos) and reflection (blue). The northern, reflection nebula component of the Trifid consists of dusty particles reflecting light from nearby stars toward us. On a dark night a 6-inch scope reveals the delicate features of this intricate complex of gas clouds and infant stars.

These wonders and many others await you along the starry spine of the Milky Way. Whether you go out into this brave new world with naked eye, binoculars, or telescope, you'll certainly come inside appreciating the musty words of Milton in describing our Galaxy and its beautiful, powdery stars. □

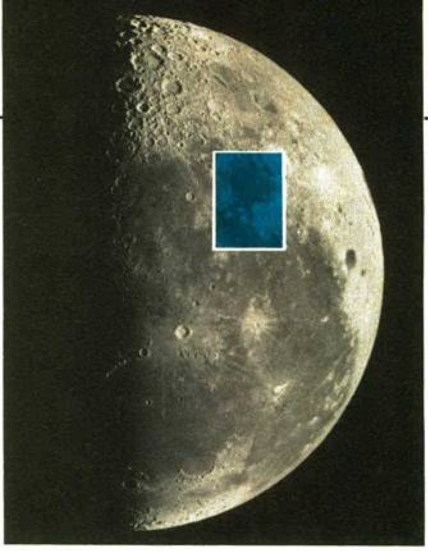


Michael Stecker

Exploring MARE HUMORUM

Read the story of the Moon's violent past in this spectacular impact basin.

by Michael T. Kitt



Gérard Therin

MARE HUMORUM STANDS OUT in the southwestern part of the Moon, shown 22 days after New Moon (above) and 11 days after New Moon (right).

Roughly 3.85 billion years ago, a huge chunk of solar system debris had its sights set on the southwestern quadrant of the Moon. The projectile smashed into the Moon, carving out a basin 510 miles in diameter and obliterating whatever features once existed there.

But the impact struck only the first blow in shaping this part of the Moon. Smaller projectiles continued to pummel the lunar surface, gouging many small and a few large craters. Then beginning about 3.8 billion years ago, successive sheets of lava flowed up through the crust fractured by the initial impact and filled part of the basin. This 220-mile-wide flooded plain is **Mare Humorum**, one of the most striking features on the Moon.

To see this lunar sea at its best, head outside with your telescope between the tenth and twelfth day after New Moon. The terminator — the dividing line between sunlight and darkness — is then crossing Mare Humorum, throwing its features into sharp relief. Let's take a leisurely tour around the mare, starting with the prominent crater **Gassendi**, which sits on the northern rim.

With a small telescope, you can see some of the changes that have altered Gassendi's appearance since a violent impact dug this 70-mile-wide hole out of the Moon's surface not long after the basin itself formed.

On Gassendi's southern rim, you can see where the mare lavas flowed up to the crater wall, engulfing and then breaching it. And look for the prominent crater **Gassendi A** that overlies Gassendi's northern rim. This 20-mile-wide crater is the youngest feature in the Humorum area, dating from about one billion years ago.

The floor of Gassendi contains a wealth of unusual detail best seen under the grazing illumination provided just after local sunrise. Even at moderate magnification, a small telescope reveals the rough, jumbled texture of the crater's floor punctuated by a group of four peaks in the center. But the highlight of Gassendi is a magnificent system of rilles — narrow grooves much longer than they are wide — that crisscross the eastern half of the crater's floor. To fully appreciate these rilles, you'll need steady seeing, moderate aperture, and high magnification.

After exploring Gassendi, shift your view to the eastern side of Mare Humorum. There you'll find what many veteran lunar observers consider the most spectacular set of rilles on the Moon. The **Rimae Hippalus** are best seen ten days after New Moon. The three main rilles run parallel to each other and to the arc of the basin. They extend about 150 miles, almost a quarter of the way around Mare Humorum. Patient observers will find many smaller rilles in this region.

The western side of Mare Humorum contains a sister set of rilles, equally as long as though not as prominent as those to the east. The Mare Humorum rilles are examples of grabens, structures that form when the land between two close parallel faults drops to a lower level.

Continuing clockwise around Mare Humorum, you'll find some unusual formations on its southern shore. In the southeast lies the isolated massif **Promontorium Kelvin**. This 13,000-foot-high mountain has steep flanks that show the effects of massive landslides in details that change from hour-to-hour as the changing angle of the Sun performs a light-and-shadow show on it.

West from Promontorium Kelvin, superimposed on the floor of Mare Humorum, lies the flooded crater **Doppelmayer**. Trace the nearly destroyed rim of this 40-mile-diameter crater around its circumference, noting how the encroaching lavas from Mare Humorum caused far greater damage than they did to Gassendi to the north.

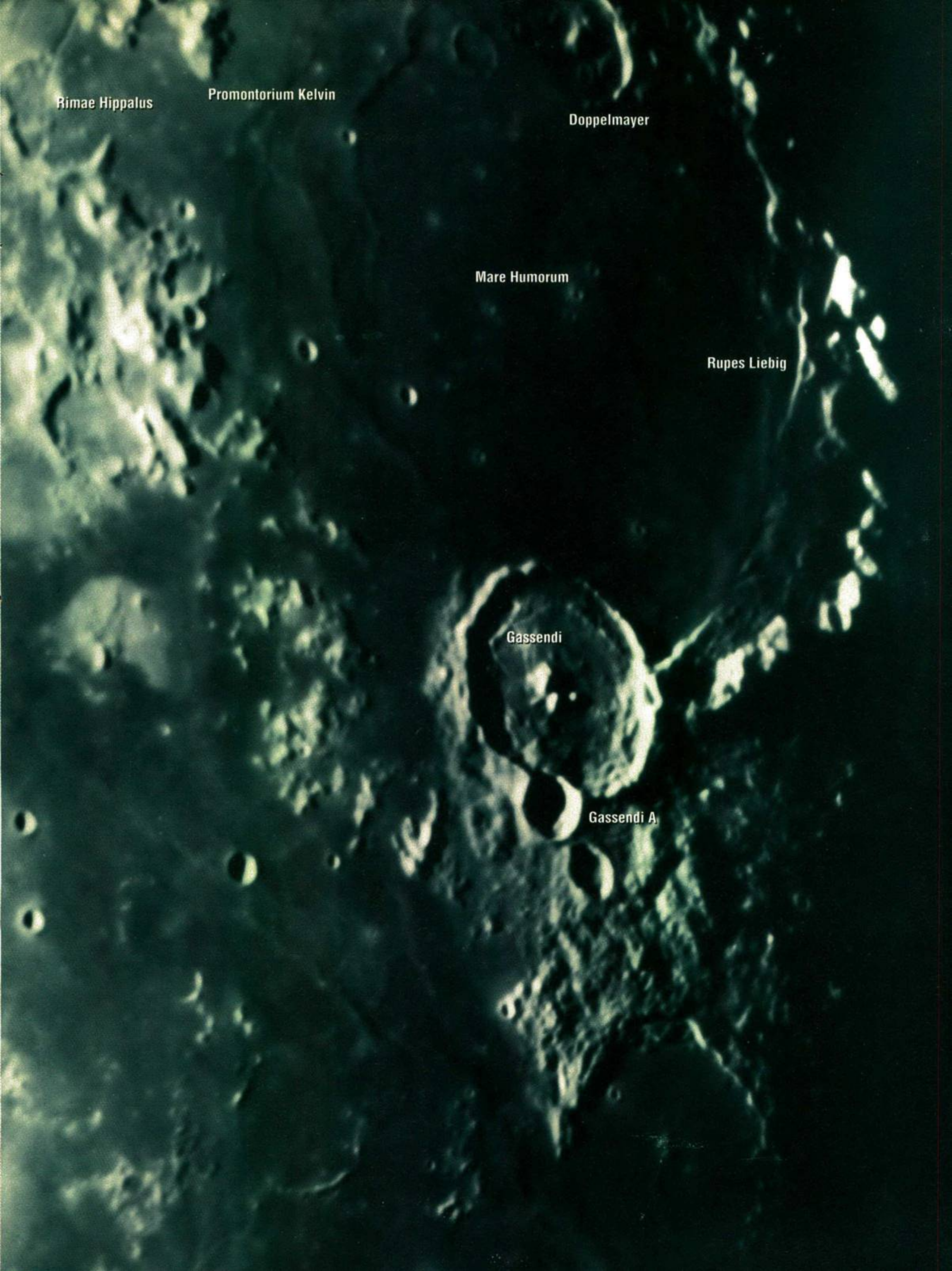
A rare lunar fault lies northwest of Doppelmayer, near the southwestern limb of the sea. Called **Rupes Liebig**, this fault appears as a bright thin line on the twelfth day after New Moon, when its eastward-facing wall catches the first rays of the rising Sun.

Our tour ends at the 50-mile-wide crater **Mersenius**, which lies off the northwestern edge of Mare Humorum (and off the edge of the photo). This crater stands out because of its convex floor. No other crater on the Moon displays this effect so obviously. Planetary scientists think the convex shape came about as lava welled up beneath the crater's solid floor.

With its unusual floor, Mersenius makes a fitting finale to our tour of Mare Humorum. This sea provides first-time lunar observers with a range of features that will help acquaint them with some of what the Moon has to offer. But these same features remain intriguing enough to keep even seasoned veterans coming back month after month. □

Michael T. Kitt is an experienced lunar observer and author of The Moon: An Observing Guide for Backyard Telescopes *(Kalmbach, 1992).*

Jean Dragesco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Mare Humorum
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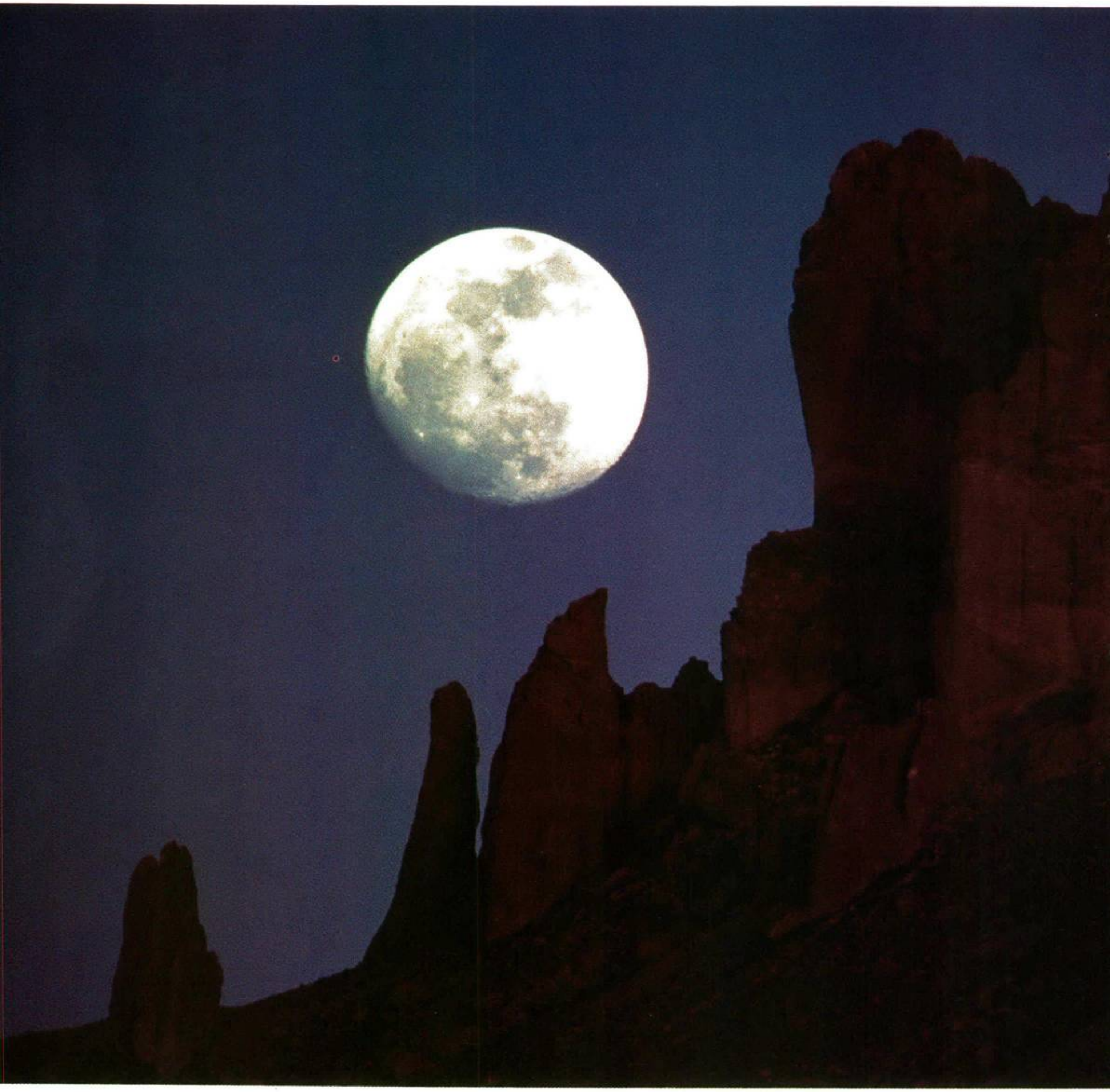
Gassendi
Gassendi A



Joining Land & Sky

Turn your ho-hum sky photos into stunning ones by including an intriguing landscape silhouette.

Story and photos by Frank Zullo

ADD PUNCH TO YOUR MOON SHOTS by double exposing the image or sandwiching it with a silhouette of an intriguing landscape.

Every astrophotographer has a collection of marvelous shots of celestial objects. But when enlarged to go on the living room wall, the images have less punch than the sky scene so vividly remembered. What's missing? The same thing that probably prompted the picture — the combined setting of sky and landscape.

Nightscapes, photos that include a landscape along with the night sky, can be breathtaking. They remind us of the Earthly platform from which we contemplate the heavens. But more often than not, something goes wrong when trying to shoot landscape and night sky at the same time — the Moon wasn't placed quite right over the beautiful dusk-colored landscape or the foreground trailed while you carefully tracked the stars.

The solution to these problems is photo manipulation: slide sandwiches, double exposures, and combinations of the two. Slide sandwiches make it easy to add a silhouetted foreground to a night-sky photo. To create a sandwich, you place a slide of a celestial object in contact with another slide showing an opaque landscape and a clear sky. The resulting composite image looks just like a scene of the sky with a silhouetted foreground.

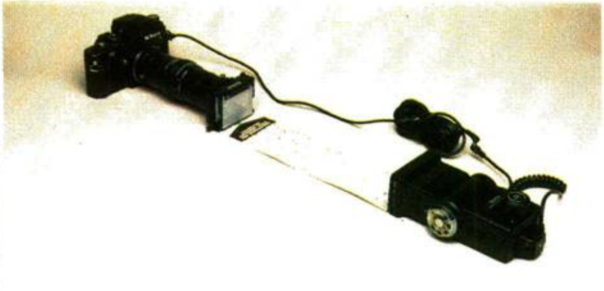
A successful slide sandwich starts with a good celestial image suitable for the background. The best photo has a little sky brightness to make the landscape silhouette pop out. You can obtain a slide with a sufficiently bright night sky in several ways. One is by making a long exposure of a dark sky with the camera mounted either on a tripod to get star trails or piggy-back on a guided telescope to capture a constellation. This shot will show the most celestial detail, but unwanted colors can emerge from distant city lights or from color shifts in the film caused by the long exposure. Kodak Ektachrome P800/1600 slide film processed at ISO 800 gives good results with little color shift. Try an exposure of about 15 to 30 minutes at f/2.8, depending on how dark the sky is.

You can also catch a nice sky shot using short exposures at dusk or dawn. Shooting at these times is difficult because twilight is short-lived and constantly changes in brightness. But capturing a twilit sky is worth the effort because of the dramatic colors. Shoot when you see only a hint of color at the horizon. The sky will be nearly dark, yet the film will see more stars than the eye can detect and still record a warm glow to form a backdrop for the foreground.

Moonlight can produce a beautiful, azure-tinted nighttime sky. Plus, capturing a moonlit sky is easier than capturing a twilit sky because the light level holds relatively stable for hours. You can choose the amount of sky brightness by simply shooting during the right lunar phase. Avoid the light of the Full Moon because it usually overpowers all but the brightest stars. Shooting near First or Last Quarter gives better control over the light level.

For either twilight or moonlight, try Ektachrome 200. The film is fast enough to capture faint stars but not so fast that the sky becomes overexposed. With the camera's aperture stop set at f/2.8, try exposures of 10 to 15 minutes during late twilight or 5 to 10 minutes during a Quarter Moon. Because conditions and the effect you want to achieve can vary greatly, exact exposure times are impossible to know ahead of time. So always bracket exposures both lighter and darker to increase the chance of success.

The Moon itself makes a good subject for a slide sandwich. A frame-filling Full Moon provides a nice light background against which to silhouette a landscape. I use inexpensive equipment to photograph the Moon — an 80mm refractor with a 1000mm focal length, a 2x teleconverter, and an adapter to attach my camera to the telescope's focuser. The resulting 2000mm f/25 system lets me capture a Full Moon high in the sky with expo-



ASTRONOMY: Jim Forbes

CREATING COMPOSITES IS EASY using a slide duplicator. Sandwich a sky scene with a contrasty foreground, then copy the sandwich onto slide film with the duplicator.

A LONE TREE FOCUSES this picture of the summer Milky Way. Adding the foreground via slide compositing enhances the image and gives it a you-are-there feel.

sures of 1/15 to 1/8 second using a film speed of ISO 50 to 100. Such a short exposure doesn't need to be guided but it does require a steady tripod.

Now that you have an exciting sky scene, it's time to make a foreground to go with it. The foreground should be totally opaque in the landscape areas and completely clear in the sky regions. Kodak Kodalith, a high-contrast black-and-white negative film, produces a good silhouette. Kodalith is mostly blue sensitive, so you can handle it in a darkroom under a red safelight. Kodak rates the film at ISO 6 and recommends processing in Kodalith A & B developer.

Kodalith's high contrast isn't enough: You must also shoot a high-contrast scene. You can do this is by shooting the landscape when the Sun lies just below the horizon. Aim the camera toward the west just after sunset or the east just before sunrise. Expose for the sky and bracket the exposure times to get the scene you want.

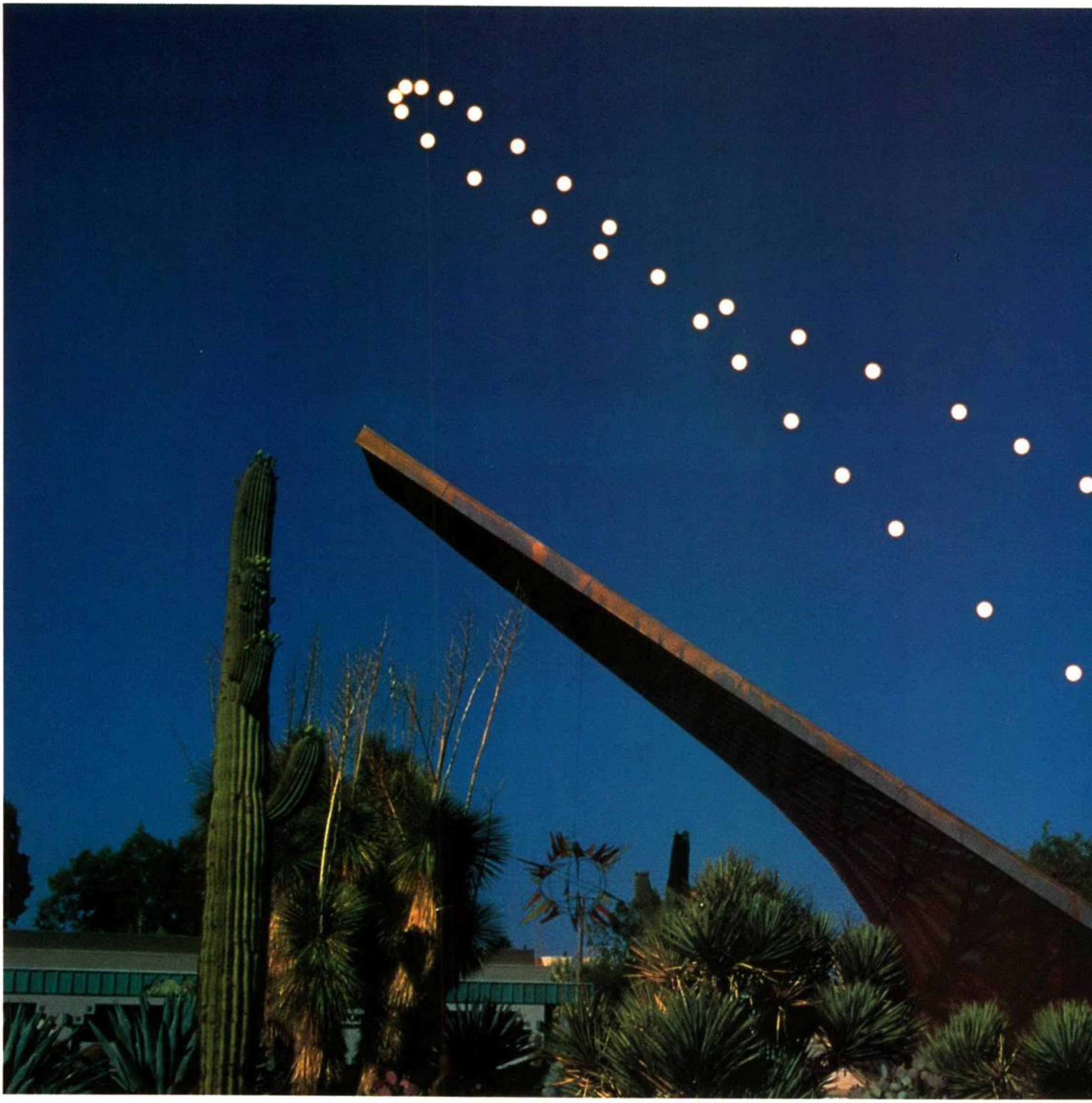
This photo produces a negative of your landscape with black skies and a white foreground. You need to copy this it onto Kodalith to make the positive necessary for the sandwich. Custom photofinishing labs can do this for you. Or you can purchase a slide duplicator available for most 35mm single lens reflex cameras.

You can now sandwich this positive of your land-

scape with the sky background. If you want to project the image on a screen, you can hold the two pieces of film together with a slide mount. Or you can copy the sandwich onto fine-grain Fuji Velvia or Kodachrome 25 using the slide duplicator. This last step can correct improper exposure and color and adds contrast that can bring out fainter detail in the sky. For less contrast, use a regular slide duplicating film such as Kodak Ektachrome Slide Duplicating Film 5071.

Astrophotographers working with negative film can also make sandwiches. Shoot the sky and foreground scenes as above but don't duplicate the foreground because it's already a negative. Print the sky first and then print the foreground on the same piece of paper. The opaque sky of the foreground's negative will prevent any exposure of the paper in these regions and leave the stars intact. The clear foreground will expose the landscape regions on the paper to white light, making that area of the final print completely black.

Another way to combine the elements of land and sky is through double exposures. Take an exposure of the starry sky and then a second one of the landscape on the same piece of film. The second exposure can be a direct shot of a scene or, using a slide duplicator, of a slide you've already taken. To make

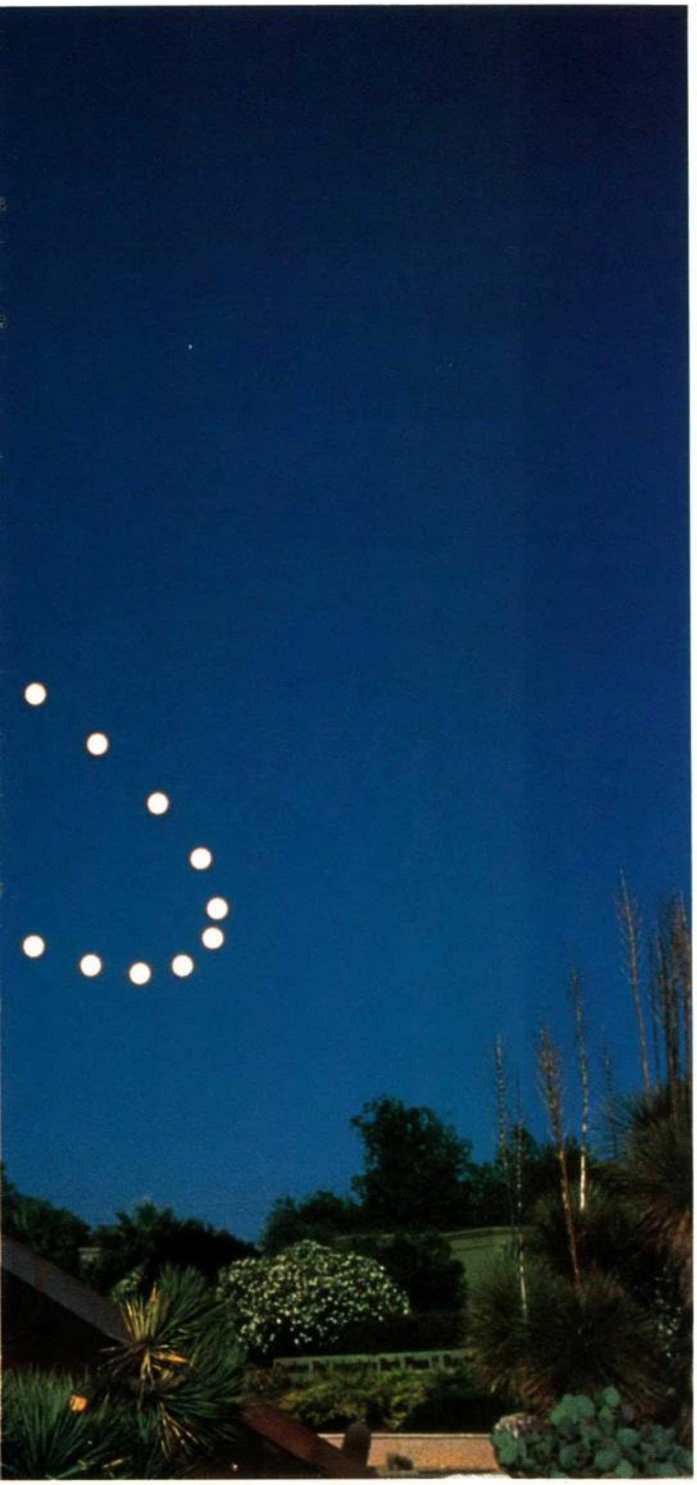


double exposures, you'll need a camera that has some means of cocking the shutter without winding the film. Most single lens reflex cameras can do this but read the camera manual for directions.

To see how to make a double exposure, imagine the Full Moon framed by your favorite landscape. But as usually happens, the Moon doesn't lie in the right part of the sky for the picture as imagined. This often occurs when using a telephoto lens to make our nearest celestial neighbor look even nearer.

First frame the scenic view, making a mental note where the Moon should appear. Expose the scene and then recock the shutter for the second exposure. Change the camera lens if you need to enlarge the Moon and frame our satellite. Using a shutter speed equal to 1 second divided by the film's ISO speed, expose the Moon at f/5.6 for quarter phase, f/8 for gibbous, and f/11 for Full. Advance to the next frame and repeat the process with some slightly different exposure combinations.

You can also employ other double exposure magic. Try an exposure at dusk that's 1 to 1½ stops darker *than the camera's meter reading*, recock the shutter, wait until twilight ends, and then open the shutter to let the stars trail in a dark sky over the pre-exposed foreground. The separate dusk expo-



THE SUN LAZILY TRACES a figure eight over the course of a year when photographed at the same time every nine days. A double exposure added the sundial.

sure gives more control over the brightness of the landscape. The alternative is trying to guess how long you need to leave the shutter open to record just the right amount of sky light.

With contrasty sky scenes on dark backgrounds, you can double expose a landscape directly onto the slide. A slide of the Moon, for example, works nicely. This method also worked great for making a picture of the analemma over a sundial (see above). The analemma is the figure eight path of the Sun caused by its apparent north and south motion in the sky through the year.

This double exposure combined a shot of the Sun's motion with that of a nearby sundial. I photographed the analemma using a camera mounted on a patio cover in my back yard, but this mounting provided no suitable view to use for the foreground. I chose black-and-white film because it's very stable and can tolerate exposure to the harsh Arizona climate for a year.

Every nine days at exactly 8:00 a.m. MST, the same piece of film captured the Sun. Then I developed the film to get a negative and copied it to make a high-contrast positive in the same manner described above for making foregrounds. The positive gave a figure eight of Suns against an opaque background — not exciting by itself but perfect for use in a double exposure.

A sundial became the foreground object because sundials often incorporate analemmas to aid in converting from solar time to standard time. I loaded a fresh role of Fuji Velvia film and made an alignment mark on the film leader before closing the camera back. I shot a whole roll of the sundial, bracketing the exposures, and then rewound the film, leaving the tip of the leader sticking out of the cassette.

When reloading the film, I used the alignment mark to make sure that winding the film would reposition each frame properly. I then double exposed the positive of the analemma onto the skies of all the sundial shots using a slide duplicator.

You can also reload an exposed roll into your camera for double exposures when you duplicate slide sandwiches. First shoot a whole roll of sandwiches containing beautiful starry skies and silhouetted landscapes as described above. Reload the roll and then go out into the night and shoot objects or people in the black foreground area of each frame using an electronic flash.

Good frame-by-frame notes will help you properly place the double-exposed objects for each shot. Make this process easier by changing the camera's regular focusing screen to one containing grid lines, if your camera permits it. Use sketches to show where to position the object or people in relation to those grid lines.

Double exposures, slide sandwiches, and combinations of these two techniques can help create many stunning images. My favorites are those based in reality but with perhaps a touch of fancy. To keep the images from getting too far out, try to stick close to how the sky actually appears, occasionally bending the rules a little to accentuate a statement or mood.

Some astrophotographers needlessly break sky rules with their composites and double exposures. The worst cases are those with an impossibly placed Moon — an image of the Full Moon over a western horizon at sunset and a crescent Moon precariously placed between Polaris and the Big Dipper. When properly done, composites take us into the landscape and make us look up at the vast heavens. More than that, they remind us that land and sky are but parts of the same universe. ☐

Frank Zullo is a commercial photographer and amateur astronomer in Scottsdale, Arizona.

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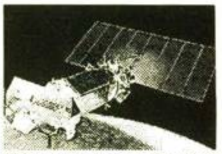

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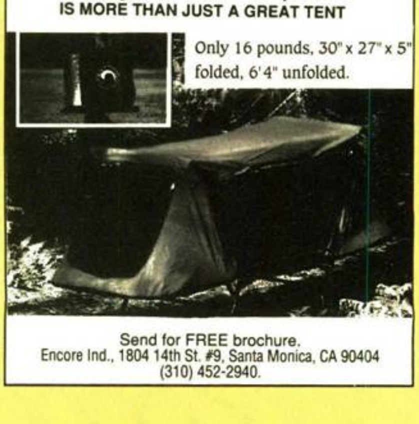

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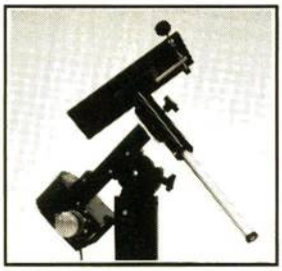

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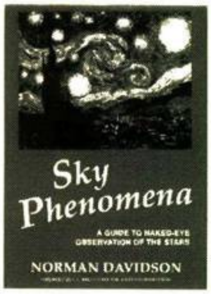

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READER REPORTS

Full Moon Tricolor CCD Imaging

Capturing galaxies, nebulae, and comets with a CCD camera is a full-time job. At least that's the attitude of Glenn Gombert and John Chumack, backyard skyshooters from Dayton, Ohio. Gombert and Chumack believe high-resolution CCD imaging should be done not only during the dark of the Moon but also when the Moon hangs in the sky. They first set out to test their imaging capabilities on the hazy, Full Moon night of July 4, 1993.

"We were inspired by hearing Richard Berry and Jack Newton's workshop at the Apollo Rendezvous in Dayton in June 1993," says Gombert. "We adapted an SBIG ST-6 CCD camera to John's homemade 16-inch f/4.5 reflector and, inspired by Newton's wonderful tricolor images, we couldn't wait to try it out."

After mounting the camera and adjusting the main telescope's 4-inch guidescope, Gombert and Chumack set their sights on the Whirlpool Galaxy (M51) in Canes Venatici, the Ring Nebula (M57) in Lyra, and the Dumbbell Nebula (M27) in Vulpecula.

"We were amazed at the first 50-second exposure of the Whirlpool," says Chumack. "The detail was impressive enough to encourage us to make some tricolor exposures." The duo exposed a series of images using red, green, and blue filters and electronically combined them to produce color images, using the exposure ratios of red=1, green=2, and blue=4. Delighted with their success, the astro-imagers repeated the process with the Dumbbell and the Ring (center, right).

Although Gombert and Chumack find that image processing enables deep-sky imaging on a Full Moon night, they also capture images during other nights of the month. They have recorded a variety of galaxies and nebulae along with several comets, including a striking tricolor image of Comet Mueller 1993a (top right). "We intend to keep imaging as many objects as we can," says Chumack, "occasionally taking a little time out for sleep and for our jobs."

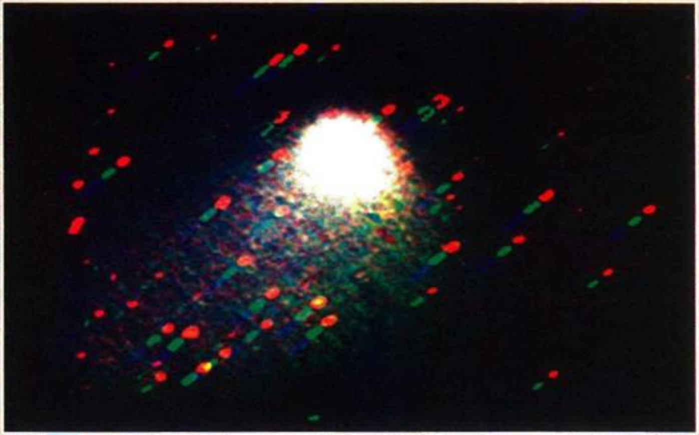
Catching a Fireball on Film. It's a rare thing to catch a bright fireball on film. Judging by this standard, Scott McAfee of Oakland, California, must have been the luckiest astrophotographer alive when in July 1992 he caught a terrifically bright bolide in his very first night of taking sky pictures.

"I had set up my camera and loaded it with ISO 400 film," says McAfee, "hoping to capture some pretty star trail shots, or maybe a Delta Aquarid meteor as it fell toward Earth. The sky was dark as I settled into my campsite at Oregon's Crater Lake National Park and watched the sparkling sky overhead."

As the night progressed McAfee kept shooting, his camera and tripod perched over a sleeping bag laid out on the ground. "I grew tired," he says, "but I kept at it, opening the shutter and then settling back down onto the sleeping bag to watch the sky." As McAfee waited patiently someone suddenly turned on the lights. The "lights" in this case turned out to be the most brilliant fireball he had ever seen. "The fireball began at the zenith and took six seconds or so to reach the tree line, flaring slightly along the way — it stopped my heart for a moment," he says.

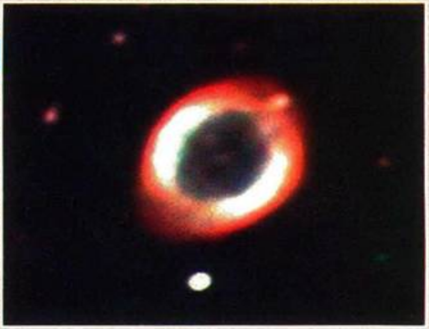
Fortunately McAfee's heart began beating again, and his exposure shows the fireball slicing through Vulpecula on its way toward the horizon — a significant and beautiful memento from a first night of astrophotography.

ASTRONOMY magazine wants to hear about your observations of the sky. Send reports, sketches, and photographs to David J. Eicher, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187. Please label each photo with your name, address, and social security number. You may send written reports via Internet to 72000.2704@CompuServe.com



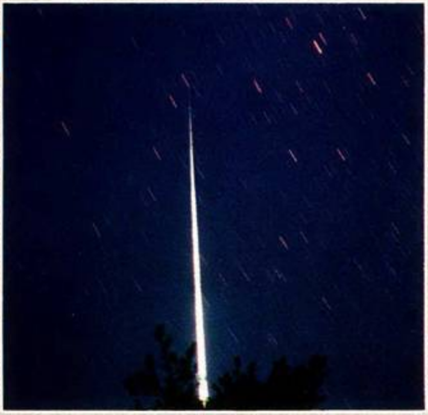
Comet Mueller 1993a

by John Chumack and Glenn Gombert (16-inch f/4.5 reflector, ST-6 CCD camera)



The Ring Nebula in Lyra

by John Chumack and Glenn Gombert (16-inch f/4.5 reflector, ST-6 CCD camera)

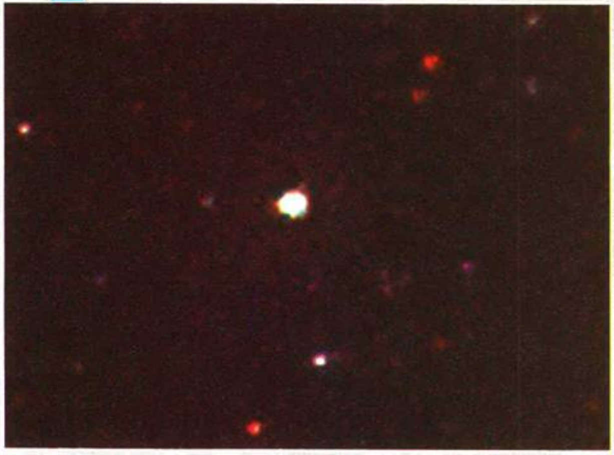


Bolide Streaks Through Vulpecula

by Scott McAfee (ISO 400 film, taken on July 27, 1992)

Nova Cassiopeiae 1993

by Jack Newton
(25-inch f/5 reflector, ST-6 CCD camera)



The Eclipsed Moon in Taurus

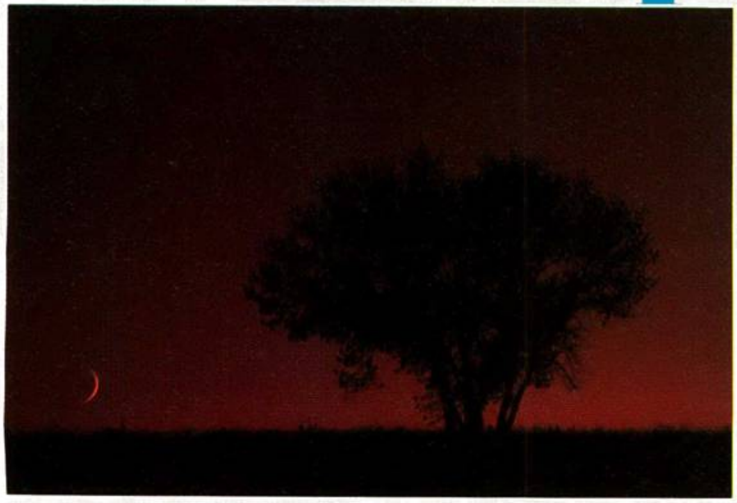
by Douglas C. Brown
(50mm lens at f/2.8, Fuji Super HG 400 film, 10-minute exposure on November 29, 1993)

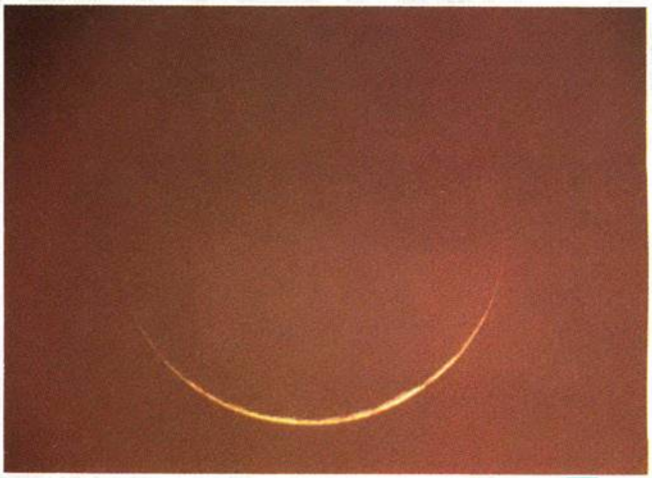
PORTRAIT OF A LUNAR ECLIPSE

The dark orange lunar eclipse that swept across North America on November 28-29, 1993, provided a wonderful show for thousands of observers. Carl Weber's image of the eclipse, a montage of 24 exposures taken over several hours, captures the whole span of the eclipse (opposite page). His image wins this month's $100 "Best Astrophoto" award.

The Moon and Venus over Billings, Montana

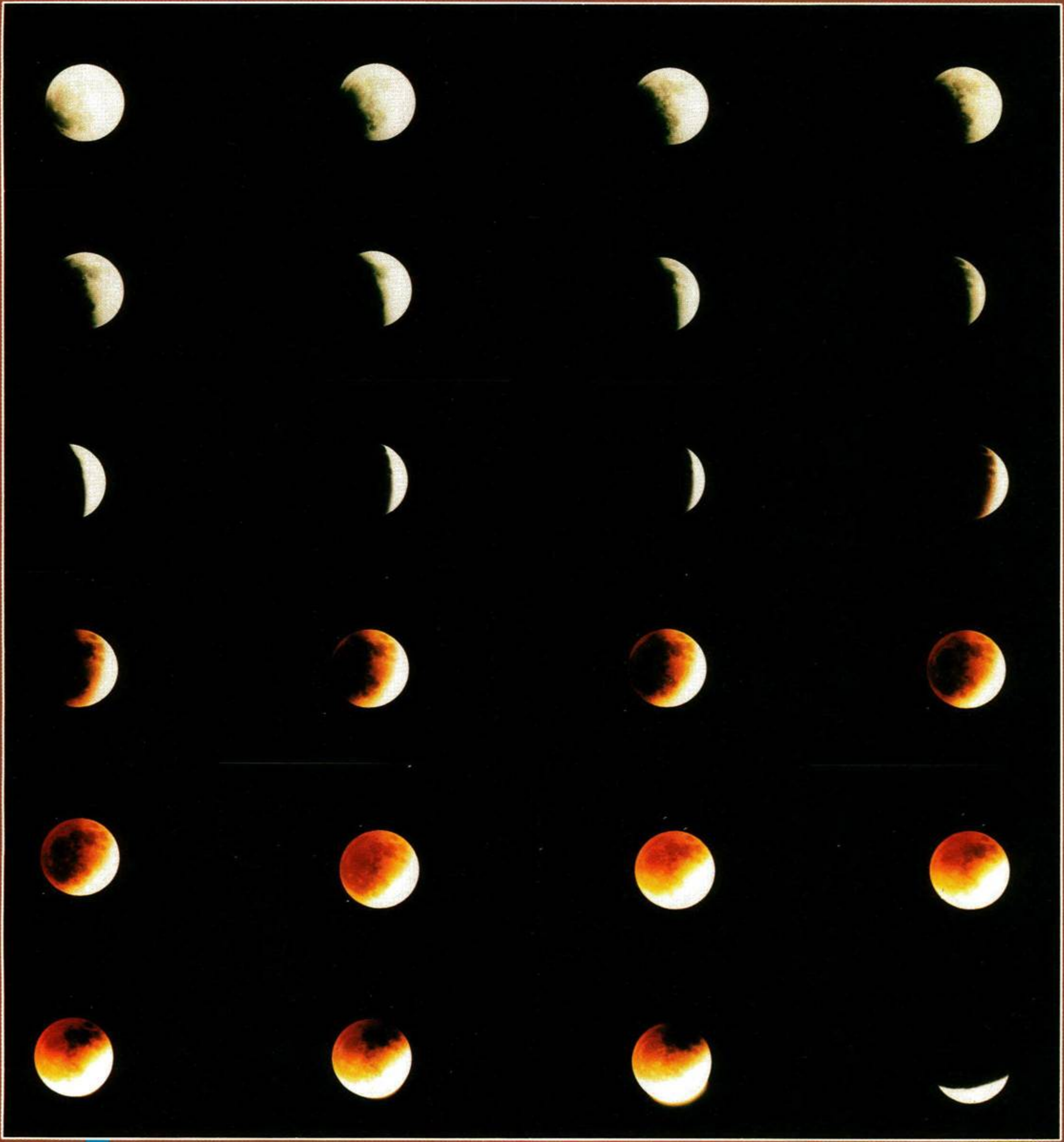
by John McNeal
(24mm lens at f/5.6, ScotchChrome 400 film pushed to ISO 800, 45-second exposure on December 10, 1993)





A 26.5-hour-old Moon

by Dan Smiley
(8-inch SCT at f/6.3, Kodak Gold 100 film, 1-second exposure on January 12, 1994)



The Lunar Eclipse of November 28-29, 1993

by Carl Weber
(4-inch SCT, Kodak ISO 400 film, montage of 24 exposures taken on November 28-29, 1993)

NEW MEADE® ADVANCED PRODUCTS AT LUMICON

"What an astounding combination of high performance and low price!" Jack Marling, Ph.D., owner of LUMICON

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EXPERT INFORMATION 1-510-447-9570 FAX 1-510-447-9589

MEADE APOCHROMAT ED REFRACTORS

7'' f/9 Apochromat

Only $5495

7'' IN STOCK!

Meade 6'' f/9 Model 152ED Refractor shown with #1697 Computer.

NOTE: Add the indicated packing and shipping (P&S) costs to each telescope for insured UPS shipment to your door.

MEADE DOBSONIANS

Drop-shipped from Meade, add shipping charge in parenthesis.

6" f/8 Starfinder Dobsonian ($39)	**$295**
8" f/6 Starfinder Dobsonian ($49)	**$395**
10" f/4.5 Starfinder Dobsonian ($69) ...	**$565**
12.5" f/4.8 Starfinder Dobsonian ($79) ..	**$765**
16" f/4.5 Starfinder Dobsonian ($45) ...	**$995***

**Shipped truck freight collect; add $45 packing charge.*

NEW MEADE EYEPIECES

Series 3000 Plossl 1¼" eyepieces: select 5mm, 6.7mm, 9.5mm, 16mm, 25mm **$59.95**

Select Any 3 . **$48.95 ea.;** Any 5 . **$46.95 ea.**

Series 3000 40mm Plossl 1¼" eyepiece **$79.95**

Shipping charges of 4-5% are extra.

See the Meade ad in this magazine for full specifications and product descriptions. ED = Extremely low dispersion glass which yields color-free virtually perfect images. PPEC = Permanent Periodic Error Correction "Smart Drive."

Model 102 ED 4" f/9 Apochromat & mount (add $105 P&S)	**$2195**
Model 127 ED 5" f/9 Apochromat & mount (add $125 P&S)	**$2795**
Model 152 ED 6" f/9 Apochromat & mount (add $185 P&S)	**$4495**
Model 178 ED 7" f/9 Apochromat & mount (add $215 P&S)	**$5495**

Medium format adapters ..... Mamiya 645, **$98;** Pentax 6X7, **$98**

Med. format EASY-GUIDER™: Mamiya 645, **$298;** Pentax 6X7, **$298**

DRIVE SYSTEMS

#1664 Electronic Drive with PPEC & 2X, 32X slewing system	**$375**
#1697 Computer Drive, 747 object computer memory, automatic slewing to desired object	**$695**

8,000 Object CNGC Library .. **$99** Polar alignment finder .. **$99**

OPTICAL TUBE ASSEMBLIES (OTA)

Model 102 ED/OTA 4" f/9 OTA only (add $55 P&S)	**$1045**
Model 127 ED/APO-OTA 5" f/9 OTA only (add $60 P&S) ...	**$1595**
Model 152 ED/APO-OTA 6" f/9 OTA only (add $100 P&S) ..	**$2295**
Model 178 ED/APO-OTA 7" f/9 OTA only (add $120 P&S) ..	**$3250**

Cradle ring assem. 4" (4½" OD tube) **$135;** 5" (5½" OD tube) **$145**

Cradle ring assem. 6" (7" OD tube) **$169;** 7" (8" OD tube) **$219**

EQUATORIAL MOUNTS

LXD 600 mount and standard field tripod (add $60 P&S) ..	**$1350**
LXD 700 mount and giant field tripod (add $100 P&S)	**$2250**

NEW MEADE 12" LX200 SCHMIDT-CASSEGRAINS

8" LX200

$2295

NEW Meade 8'' LX200 Telescopes

See the Meade ad in this magazine for full specifications & details. **LX100 Drive**, 2X, 32X speed control with PPEC (Permanent Periodic Error Correction "Smart Drive") & dual-axis hand controller. **LX200 Drive**, Full electronic control with PPEC, 747 object computer memory and automatic computer controlled slewing to desired object. *NOTE:* A wedge is **not** needed for visual observing with the LX200 Drive. Select f/10 or f/6.3 (no extra charge) for your Schmidt-Cassegrain.

8'' LX100 Schmidt-Cassegrain with wedge (add $105 P&S) .	**$1995**
8'' LX200 Schmidt-Cassegrain with computer (add $105 P&S)	**$2295**
Wedge for photographing with 8" LX200	**$110**
10'' LX100 Schmidt-Cassegrain w/super wedge (add $145 P&S)	**$2895**
10'' LX200 Schmidt-Cassegrain with computer (add $145 P&S)	**$2895**
NEW! 12'' LX200 (f/10 only) with computer (add $215 P&S)	**$3995**
Super Wedge for photography with 10" or 12" LX200	**$395**
8,000 Object CNGC Library (Version 2.5 software)	**$99**
Library Option 1: 10,600 NGC, Messier, IC objects (Ver. 3.2 only)	**$99**
Library Option 2: 64,350 celestial objects (Version 3.2 only) ..	**$149**

OTHER SCHMIDT-CASSEGRAINS

Meade 2045D 4" f/10 with motor drive (add $40 P&S)	**$699**
Meade 2080B 8" f/10 with tripod, wedge, MCOG (add $85 P&S)	**$1149**
NEW! Model 2120B 10" f/10 w/wedge, tripod, MCOG (add $125)	**$1449**

PHOTOGRAPHY ACCESSORIES

LUMICON Cassegrain EASY-GUIDER 4", 8" only, f/6 or f/10 .	**$225**
LUMICON Giant EASY-GUIDER for 10" or 12" f/4-f/10 operation	**$395**

MEADE STARFINDERS

8" f/6

$699*

New 8'' f/6 Meade Starfinder telescopes

See the Meade ad in this magazine for full descriptions and technical specifications for 6" to 16" Starfinders. These are complete telescope systems with motor drive, mount, finderscope and 25mm (=48X) eyepiece.

6'' f/8 Starfinder 6(add $65 P&S)	**$599**
8'' f/6 Starfinder 8 (add $75 P&S)	**$699**
10'' f/4.5 Starfinder 10 (add $90 P&S)	**$799**
16'' f/4.5 Starfinder 16 (ship. freight COD) .	**$2195**

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated shipping charge to the price. LUMICON showroom prices are $99 higher.

ACCESSORIES

LUMICON carries the full line of Meade accessories. See the Meade ad in this magazine for detailed prices and descriptions.

LUMICON Single axis drive corrector .	**$99**
LUMICON DX200 Dual-axis drive cor.	**$249**
Meade 47M Dual-axis drive corrector	**$450**
LUMICON DX2BP Dual-axis drive corrector with built-in battery pack	**$299**

LUMICON® SKY VECTOR™

Higher Performance — Lower Price

LOW PRICE—from $399

LUMICON SKY VECTOR FEATURES:

- "GUIDE" mode leads you to object
- Digital right ascension readout to 1 min.
- Digital decl. readout to 10 arc-min.
- 4000 pulse (0.09° accuracy) encoders
- Polar alignment ***not required!***
- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, etc.

SKY VECTOR I™ $399

NEW! With over 220 object memory including the 110 Messier and 58 best NGC objects.

SKY VECTOR II™ $499

IMPROVED — Planets, Over 3,700 Objects! With size, magnitude and full visual description.

NGC SKY VECTOR™ $699

IMPROVED!—5500 Additions / Corrections

NGC-Sky Vector
OFF ON
DIM
MODE
ENTER
UP
DOWN
LUMICON

Improved NGC SKY VECTOR with over 12,000 object memory including the planets, complete, corrected RNGC catalogue, IC catalogue, P&K planetary catalogue, & much more!

Specify Telescope Type: Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17½, Alt-Azimuth.

Ultima 8, 11 .. **add $25**, C-14 .. **add $75**

LUMICON ACCESSORIES

LUMICON, 2111 Research Dr., #5, Livermore, CA 94550 (510) 447-9570 FAX (510) 447-9589

COMA CORRECTOR

Coma 1 inch off-axis 17½'' f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. **It threads into LUMICON 2'' EASY-GUIDERS for effortless installation.** This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Clear aperture = 1.8".

LUMICON 48mm Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2" EASY-GUIDER .	**$169.50**
2" EASY-GUIDER (Mamiya 645)	**$199.50**
2" Adapter for Pentax 6X7 ...	**$129.00**
2" Adapter for Hasselblad .	**$229.00**
2" Adapter for Bronica SQ-A	**$175.00**
2" Extension for viewing ...	**$26.00**

2'' DELUXE BARLOW

1.8x Multiplier Lens (2'' Barlow)

LUMICON 1.8x Multiplier Lens (2" Barlow) **$235.00**

LARGE UV/DUST SEAL

Protect the optics of your 8-14" Schmidt-Cassegrain with a UV/Dust Seal. Simply thread it onto the rear cell, then attach all normal accessories. The large size fits Meade 2120, Celestron-11 and -14 & has a high quality multi coated (removable) 72mm UV filter.

Deep-Sky Filter/Dust Seal for C-8, 2080 ...	**$119.50**
UV/Dust Deal for Celestron C-8 ...	**$39.00**
UV/Dust Seal for Meade 2080, 2045	**$39.00**
UV/Dust Seal (large) for Meade 2120	**$89.50**
UV/Dust Seal for Celestron-11, -14 .	**$89.50**

LOW PROFILE FOCUSERS New! Thread-on for Odyssey

FROM $59.50

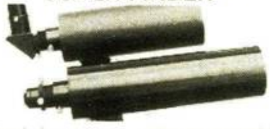
LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape! Coulter Odyssey (thread-on installation), Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD.

LUMICON 1¼'' Helical Focuser	**$59.50**
LUMICON 2'' Helical Focuser 1½" high	**$65.00**
LUMICON Non-rotating Helical Focuser	**$129.00**
2" Astro Systems focuser, only 2" high	**$139.00**
3 handles for non-rotating focuser	**$12.95**
2"/1¼" **adapter** w/48mm filter threads	**$20.00**
2'' LUMICON EASY-GUIDER	**$169.50**

LUMICON 50mm, 80mm SUPER-FINDER™



Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼" 50mm Finderscope **$59.50**, right-angle **$59.50**

1¼" straight-thru 80mm SUPER-FINDER ...	**$169**
1¼" right-angle 80mm SUPER-FINDER ..	**$179.50**
1¼" right-angle version, w/star diagonal	**$209**
25mm Cross-hair 1¼" eyepiece (12X)	**$39**
Large mounting rings for 80mm Finder	**$55**

1¼" Star Diagonal **$39**, Mounting Brackets, **$39.50**

1¼" 45° diagonal for correct left-right views **$52.44**

LOTS OF ADAPTERS

2" adapter for C-8, Meade 2080, etc. ..	**$26.00**
2" adapter for C-80, C-100 refractor ...	**$39.50**
2" adapter for C-70, C-80F, C-100F fluorite	**$39.50**
2" adapter for C-6, Comet Catcher, Meade 312	**$30.00**

EXTENSION TUBES

1" long 1¼" OD thread-in extension ...	**12.00**
2½" long extension (holds 1¼" filters) .	**16.00**
4½" long extension for 1¼" eyepieces	**$25.00**
3" long extension for 2" eyepieces* ..	**$26.00**
2" long extension for 2" eyepieces* ..	**$26.00**

VIEWING ADAPTERS

2"/1¼" reducing bushing, threaded 48mm*	**$20.00**
2"/T-thread adapter, threaded 48mm* ..	**$25.00**
T-thread/1¼" adapter	**$25.00**
F/10 2" or 1¼" eyepiece viewing adapter for Giant Easy-Guider	**$39.50**
Low profile star diagonal eyepiece holder	**$16.00**
Meade 2" Diagonal/Giant Easy-Guider	**$39.50**

**Threaded to hold 48mm filters.*

Meade & Celestron
LUMICON Carries a full line of telescopes & accessories. Fast Delivery, competitive prices.

LUMICON FOR HIGH PERFORMANCE

ASTROPHOTO OF THE MONTH

Galaxy M-51 in Coma Venatici. 60 minute photo by Tony Hallas and Daphne Mount using hypered 2415 film, C-14 at f/7.5 with a LUMICON Giant Easy-Guider. *If it weren't for your accessories, these astrophotos wouldn't be possible,*" said Tony.

"I'd Pick The TELE VUE™"

40mm Wide-Field Test, "Astronomy," Aug. 1990, p. 90

Genesis 4" f/5 4 element fluorite	$1885
Pronto 70mm f/6.4 apochromat w/2" diagonal	$825
Pronto 70mm f/6.4 w/45° erecting prism	$725
Renaissance-SDF 4" f/5.4, brass	$2095
Gibralter mount with ash wood tripod	$495
7.4, 10.4, 13, 17, 21, 26mm Plossl 50°	$79
1.8x or 2.5x Tele Vue Barlow Lens	$89
2" Giant Barlow - 2x	$169
32mm Plossl, widest true field in 1¼"	$109
55mm 2" Plossl, widest possible field	$219
15mm Wide-Field, 1¼" eyepiece, 65°	$135
19mm Wide-Field, 1¼" eyepiece, 65°	$145
32mm Wide-Field, 2" eyepiece, 65°	$239
40mm Wide-Field, "Rich-Field!" 65°	$299
4.8mm Nagler, 82° field, 1¼" eyepiece	$149
7mm Nagler, 1¼" eyepiece, 82° field	$189
9mm Nagler, 82° field, 1¼" or 2"	$219
13mm Nagler, 82° field, 1¼" or 2"	$249
12mm Nagler, Type II, 82°, 1¼"/2"	$249
16mm Nagler, Type II, 82°, 1¼"/2"	$289
20mm Nagler, Type II, 82°, 2" only	$340
1¼" Paracorr Visual Coma Corrector	$159
2" Paracorr Visual Coma Corrector	$249
NEW! 15mm Panoptic 1¼", 68° field	$199
NEW! 22mm Panoptic 1¼"/2", 68°	$249
NEW! 27mm Panoptic 2", 68° field	$299
NEW! 35mm Panoptic 2", 68° field	$325

ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.
LUMICON Adjust. Piggyback Mount $59.50
Specify telescope size: 6", 8", 10", 11", 14", 16"

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	**H-Alpha**	**(MV)**
46, 48, 49mm	$59.00	$49.00
52, 55, 58, 62mm	$69.00	$59.00
67, 72, 77mm	$79.00	$69.00
82mm	$89.00	N/A

Hypered 2415 film, 36 exp .. **$11.95, $3/$32**

NEW! ENHANCED ALUMINUM DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 2.1" enhanced aluminum diagonal mirrors & 1¼" star diagonal.

The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 94-96% compared to 86-89% for standard aluminum coated mirrors. The extra 5-10% transmission is like adding up to an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32" **$39.50** 1.52" **$45.00** 1.83" **$49.50**
2.14" **$59.50** 2.60" **$75.00** 3.10" **$99.50**

ENHANCED ALUMINUM STAR DIAGONAL

90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror)	$99.50
2" (1.83" mirror)(see photo above)	$165.00

LUMICON FILTERS — BEST IN THE WORLD!

"The LUMICON OIII proved to be our favorite... It gave the greatest contrast gain."
ASTRONOMY February 1991

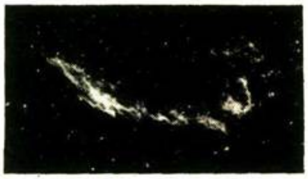
AMAZING OIII FILTER™

Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

The ultimate in filter performance! The Lumicon Oxygen-III Filter has a contrast twice as high as the high performance Lumicon UHC Filter™. Use the Oxygen-III Filter for observing the very faintest planetary and diffuse emission nebulae. Also gives incredible views of bright nebulae (like M-27, M-17, etc.) from urban locations. Bandpass is 11nm, transmission is 90-96% for both O-III lines at 496nm and 501nm.

SEE THE HORSEHEAD!

Horsehead Nebula in Orion. This faint nebula is seen best with a LUMICON H-Beta Filter. Photo by J. Marling using a Deep-Sky Filter.



"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Rich Zepernick, Cresskill, NJ

DEEP-SKY FILTER™

BEST for Astrophotography!

"Stunning is all I can say," says noted astrophotographer Jack Newton. Great for BOTH color and black and white photography.

BEST WIDE-BAND FILTER!

"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for ***reflection*** *nebulae."*
Astronomy, Feb. 1991

	Premium*
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces	$59.50
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces	$79.50
48mm LUMICON DEEP-SKY Filter (1.7" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	$119.50
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	$119.50
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)	$299.50
2" Rear Cell Filter, fits SCT's ... Deep-Sky, **$119.50** UHC, O-III, H-Beta,	$199.50
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	$99.50
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	$199.50
Set of both premium **DEEP-SKY** and **UHC Filters** (Save 11%) ... 1¼" **$159.50**; 48mm	$279.50
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼"** ... **$99.50, 48mm**	$199.50
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines ... **1¼" $99.50, 48mm**	$199.50
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm	$6.95
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece	$16.00
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece	$20.00

**Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.*

DEEP-SKY ASTROPHOTOGRAPHY

SR-V 3200 NEW FILM

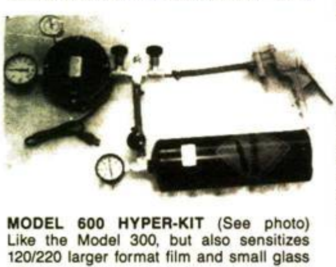
FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15x film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$325**



MODEL 600 HYPER-KIT (See photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$395**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller ... **$595**

Temperature controller for any HYPER-KIT **$65**

Electric Vacuum Pump, Model R-10 **$325**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars.
Specify Camera and Telescope type.
U.S. Patent 4,448,500

NEWTONIAN EASY-GUIDER™

Full aperture. Installs in seconds. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	$189.50
3X Relay Diagonal (see photo)	$89.50
Illuminated reticle eyepiece, pulsed	$109.50

Guider for Hasselblad **$409,** Mamiya 645 **$199**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$249.00**
Adapter for Hasselblad **$225,** Mamiya 645 **$98**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) ..... **add $99.95**
Adapter for Hasselblad **$295,** Mamiya 645**$149**
Pentax 6X7 **add $129;** Pentax 645 **add $149**

WHAT DO YOU NEED?

1. Illuminated reticle eyepiece **$99.50**
Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, battery pack.

2. Cable release for long exposures .. **$9.95**

3. **LUMICON Digital Drive Corrector** . **$249**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 30Hz/90Hz variable output controls telescope drive. 60Hz digital reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Dec. reverse switch for Newtonians.
Declination motor (state telescope) ... **$109**
Variable dec. speed drive w/built-in 5AH battery **$299**

NEW
SRV3200

HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.). ***No C.O.D.s.***

Film Type, 35mm	**Exposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	$11.95
SR-G3200, fastest of all, color neg	24	$13.95
Kodak Ektar 1000 fast, fine grain	24	$12.95
Fuji HG400 fine grain color neg.	12	$13.95
Scotchrome 400, fast slide film	12	$12.95
Fujichrome RD100, fine grain slide	24	$12.95
D-19 B&W Developer	1 gal.	$6.95

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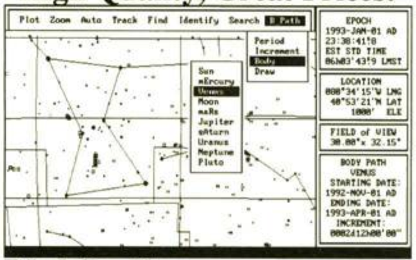
LUMICON Products catalogue FREE
All foreign orders add 8% ($10 minimum)
California residents add 8.25% tax.
Prices subject to change w/o notice.
Hrs: M-F 9 am - 5 pm, Sat. 11 am - 3 pm

Astronomy Software

High Quality, Great Prices!



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080°34'15"W LNG
40°53'21"N LAT
1000' ELE

FIELD of VIEW
30.00°x 32.15°

BODY PATH
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STARTING DATE:
1992-NOV-01 AD
ENDING DATE:
1993-APR-01 AD
INCREMENT:
0002d12h00'00"

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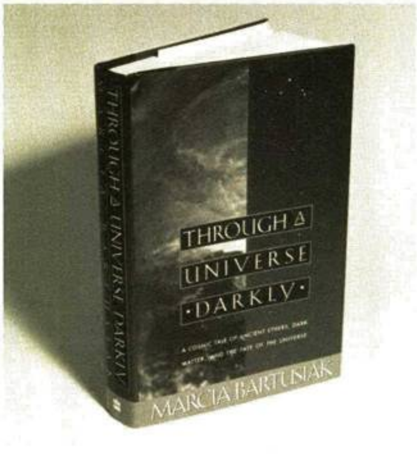
Matter in the Universe

Through a Universe Darkly

Marcia Bartusiak, (HarperCollins Publishers, 1993), ISBN 0-06-018310-1, 383 pages, hardcover, $27.50.

If you're going to buy only one astronomy book this year, this should be the one. Bartusiak's blending of science and anecdotes is marvelous. She faithfully details the struggle of scientists through the millennia to discover the nature of matter, from early Greek ideas that the universe consists of earth, air, water, and fire to the present battle to understand how most of the universe could be made of unseen or dark matter.



ASTRONOMY: Jim Forbes

But the issue reaches beyond science. Conceptions of the universe engage philosophy as well. Personalities also enter the fray, sometimes promoting and sometimes diverting progress. Bartusiak skillfully blends these components, presenting a superb description of modern astronomy and especially the search for dark matter.

The first half of the book discusses early views of matter, the birth of the atom, the promotion and dismissal of the idea that an ether permeates space, and the development of astrophysics. As astronomers learned how stars and the cosmos work, they realized that the early universe created hydrogen and helium and stars produce almost all other elements. Stars belch these newly created elements out into space, enriching the vast gas clouds in which new stars may form. A discussion of the rich chemical species contained in these clouds concludes this section.

The second half traces the study of dark matter starting with its discovery by Fritz Zwicky. He noticed that the motions of galaxies in clusters couldn't be explained unless a large amount of unseen matter existed in the cluster. The dark matter fires smoldered until Vera Rubin discovered that large amounts of dark matter must exist around galaxies to explain the orbits of stars inside them. After that, astronomers no longer questioned the existence of dark matter and established that up to 98 percent of the universe is dark matter.

What form does this unseen matter take? No one knows for sure, but Bartusiak outlines the possibilities — intergalactic gas, Jupiter-sized planets, failed stars called brown dwarfs, and exotic high-energy particles such as WIMPs and axions. Whatever its form, dark matter by its predominance over visible matter will control the fate of our universe. The practical questions concerning the form and nature of it lead to the greater ones concerning how our universe formed and how it will end. This discussion provides a fitting conclusion to Bartusiak's excellent book. — *Dave Bruning*

Other Books Noted

Traveler's Guide to the Solar System

Patricia Barnes-Svarney, (Sterling Publishing, 1993), ISBN 0-8069-8672-7, 80 pages, hardcover, $14.95.

This children's book provides an excellent introduction to the planets in our solar system. It has dozens of color images, usually from the most recent spacecraft to fly by the planet. Barnes-Svarney describes the atmosphere, geology, rings, and satellites appropriate to each planet from Mercury to Pluto, ending with Earth. This is a great gift idea for a youngster interested in astronomy.

The Evening Star

Henry S. F. Cooper, (Farrar, Straus, and Giroux, 1993), ISBN 0-374-15000-1, 274 pages, hardcover, $22.

Cooper, a noted writer at *The New Yorker*, tells the story of the Magellan spacecraft that orbits Venus and of the scientists who built the craft and use it to explore our sister planet. He captures the excitement — and tension — as the spacecraft entered orbit around Venus and describes the stress endured by the scientists when they lost the signal from Magellan. As usual, the engineers at the Jet Propulsion Lab and Martin Marietta solved the problem causing the lost signal.

(continued on p. 89)

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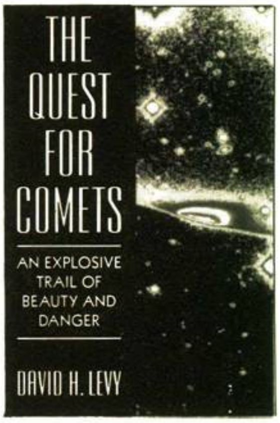

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Cooper provides a behind-the-scenes look at how planetary science is done. As data arrived from Venus, he stepped into the offices of planetary astronomers to learn what the new radar maps say about the planet's geology. He describes the craters, volcanoes, pancake-shaped domes, and thousand-kilometer domes called coronae. The Evening Star is well written but it does have one flaw: It doesn't contain any images besides two maps of Venus on the endleaves.

Sky Phenomena
Norman Davidson, (Lindisfarne Press, 1993), ISBN 0-940262-56-8, 202 pages, softcover, $19.95.

Don't let the subtitle, *A Guide to Naked-Eye Observation of the Stars,* confuse you. The book isn't a sky guide but a manual that explains why the Moon and planets appear where they do in the sky. Davidson uses the apparent motions of the planets through the sky to uncover the nature of their orbits. This discussion prompts a description of the Copernican revolution and the laws of planetary motion developed by Kepler. He finishes with a long chapter of astronomical poetry.

ASTRONOMY 1993 Bound Volume
(Kalmbach Publishing Co., 1993), hardcover, $34.95.

If you like keeping all your copies of ASTRONOMY in one place and intact, then you'll want this bound volume that includes all 12 issues of the magazine for 1993 as well as the special buyer's guide inserts as originally printed.

Möbius and His Band
John Fauvel, Raymond Flood, and Robin Wilson, editors, (Oxford University Press, 1993), ISBN 0-19-853969-X, 172 pages, hardcover, $29.95.

August Möbius (1790-1868) is best known for the band of paper that turns inside out and bears his name. But few people know that Möbius earned a living as an astronomer, not a mathematician. Möbius concentrated his astronomical efforts in the study of orbits and wrote several popular books on astronomy.

The band referred to in the book's title isn't the topsy-turvy band of paper. Rather it refers to the German astronomers and mathematicians besides Möbius who helped transform nineteenth-century Germany from an also-ran in mathematics to a world power. The authors discuss the contributions of Möbius and explore the conditions that led to the growth of German scientific prowess. □

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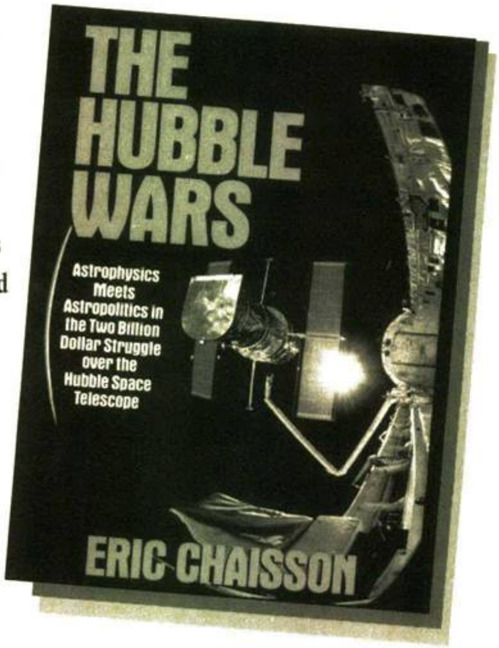
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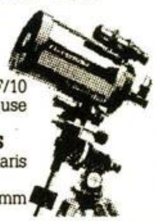

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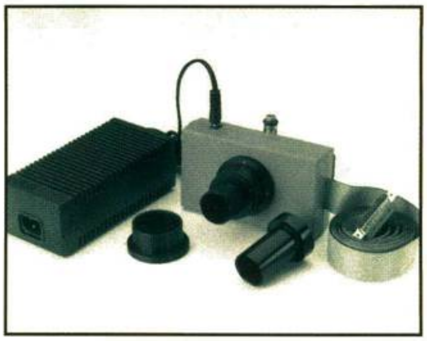

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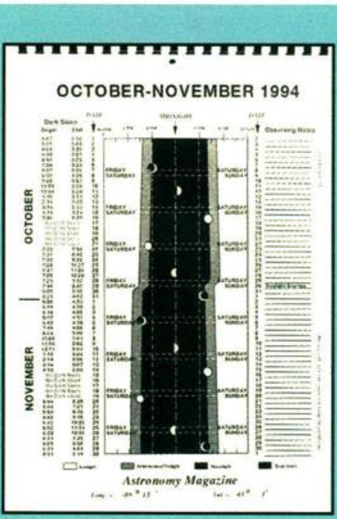
CCD Technology, 18092 Sky Park South, Unit E, Irvine, CA 92714, (714) 752-2442, fax (714) 752-2443. $495.



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Gibeon Designs, P.O. Box 65863, Tucson, AZ 85728-5863, (602) 887-2122. $12.95 per calendar, plus $1.50 shipping and handling.

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Jim's Mobile Inc., 810 Quail Street, Unit E, Lakewood, CO 80215. (303) 233-5355. $329.

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Davis Instruments, 3465 Diablo Avenue, Hayward, CA 94545, (510) 732-9229. $195.

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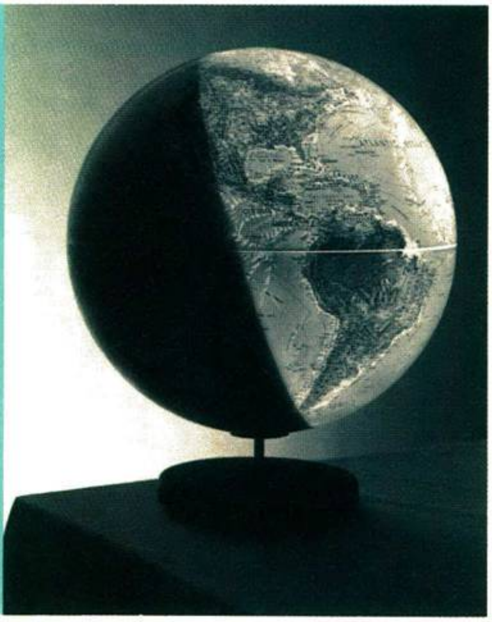
Scientific Universe Products, 5715 Sunset Lane, Mukilteo, WA 98275, (206) 355-5314. $390.



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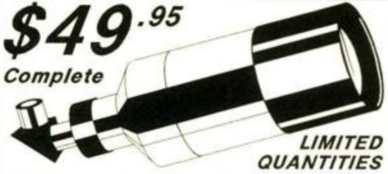
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MEETINGS & EVENTS

May 9-15
Texas Star Party, Prude Ranch, near Fort Davis, Texas. Hosted by the Southwest Region of the Astronomical League. Contact TSP Registrar, 1326 Mistywood Lane, Allen, TX 75002.

June 9-12
Astroblast '94, Oil Region Observatory, near Oil City, Pennsylvania. Sponsored by the Oil Region Astronomical Society. Contact Tom Bemus, c/o The Camera Infirmary, 120 East 3rd Street, Jamestown, NY 14701, (716) 664-4506 or (716) 386-4566.

June 9-16
Astronomy Camp for Teens (Basic), University of Arizona, Tucson, Arizona. Sponsored by the University of Arizona Alumni Association. Contact Lisa Roubal, 1111 N. Cherry, Tucson, AZ 85721, (602) 621-5233 or (800) 232-8278 outside Arizona.

June 10-11
24th Apollo Rendezvous and Telescope Fair, Dayton, Ohio. Sponsored by the Miami Valley Astronomical Society. Contact Kerry Harman, 2600 DeWeese Parkway, Dayton, OH 45414, (513) 837-4343.

June 10-12
Fifth Annual Mason-Dixon Star Party, Spring Valley County Park, Pennsylvania. Sponsored by the York County Parks Astronomical Society. Contact Todd Ullery, R. D. #1, Box 5AA, Glen Rock, PA 17327, (717) 235-1153.

June 10-12
Jersey Star Quest IV, Beemerville 4-H Camp off Route 519 (near High Point State Park), Sussex, New Jersey. Sponsored by the Amateur Astronomers Association of Princeton, Inc. (AAAP). Contact Victor Belanger, director, AAAP, P. O. Box 2017, Princeton, NJ 08543.

June 11
Spring Star Party, Portsmouth Campus, Tidewater Community College, Virginia. Sponsored by the Tidewater Community College. Contact R. H. Stewart, 1064 Dune Street, Norfolk, VA 23503, (804) 583-9397.

June 14
1994 Comet Crash Lecture, H. R. McMillan Planetarium, Vancouver, B.C., Canada. Sponsored by H. R. McMillan Planetarium and the RASC–Vancouver Centre. Contact the H. R. McMillan Planetarium, 1100 Chestnut Street, Vancouver, B.C., V6J 3J9 Canada, (604) 736-4431.

June 16
Monthly Observatory Night, Phillips Auditorium, Harvard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts. Contact Harvard-Smithsonian Center for Astrophysics, Public Affairs Office, 60 Garden Street, Cambridge, MA 02138, (617) 495-7461.

June 25
Ninth Annual Sedona-Verde Valley Astronomy Festival, Red Rock State Park, between Sedona and Cottonwood, Arizona. Sponsored by Verde Valley Astro-Center. Contact Russell Nidey, Verde Valley Astro-Center, 1101 Zalesky Road, Cottonwood, AZ 86326, (602) 634-7332.

June 25-26
Universe 94, Northern Arizona University, Flagstaff, Arizona. Sponsored by the Astronomical Society of the Pacific and ASTRONOMY. Contact the Astronomical Society of the Pacific, Meeting Information, 390 Ashton Avenue, San Francisco, CA 94112, (415) 337-1100.

June 26-27
National Workshop on Teaching Astronomy in Grades 3-12, Northern Arizona University, Flagstaff, Arizona. Sponsored by the Astronomical Society of the Pacific. Contact Sally Stephens, Teachers' Workshop, Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112, (415) 337-1100.

June 28-July 5
Astronomy Camp for Teens (Advanced), University of Arizona, Tucson, Arizona. Sponsored by the University of Arizona Alumni Association. Contact Lisa Roubal, 1111 N. Cherry, Tucson, AZ 85721, (602) 621-5233 or (800) 232-8278 outside Arizona.

July 8-9
Gateway to the Universe '94, Munro Park, Powassan, Ontario, Canada. Sponsored by The North Bay Astronomy Club. Contact Merlin Clayton, 50 Van Horne Circle, North Bay, Ontario, Canada P1A 3L3, (705) 472-1182. □

Clubs, please submit announcements at least four months before the date of the meeting or event. Readers, when you write to organizations listed in Meetings and Events, include a self-addressed, legal-sized envelope with your request for information.

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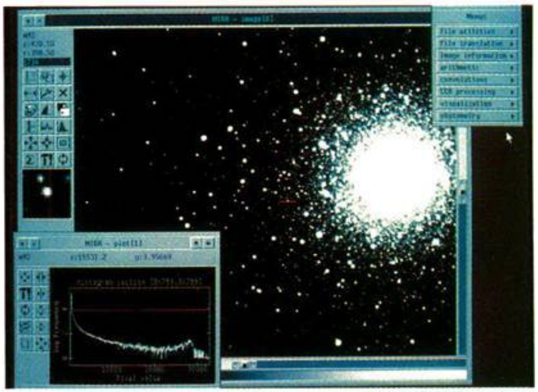
(Note: The image that appeared in the April Astronomy advertisement was, through a production error, degraded in quality.)

ASTROBYTES

MIRA (version 2.06)
Axiom Research, 1304 East Eighth Street, Tucson, AZ 85719, (602) 791-2864. Price: $595 plus $10 shipping in North America. Minimum requirements: 20 MHz 80386-based computer, math coprocessor, 4 MB of memory, hard disk with 2 MB of free space, DOS 5.0, Super VGA display with 1 MB of video memory (check with Axiom Research for models supported), and a mouse. Recommended: 80486DX-based computer and 8 MB of memory. MIRA supports laser printers with 600 dots-per-inch resolution.



ASTRONOMY: Darla Evans

Power — that's what this image-processing program is all about. It uses the 32-bit computing capability of an 80386- or 80486-based machine to quickly calibrate, enhance, and analyze large images.

MIRA includes all of the functions you need to calibrate a CCD image. A "Combine" function adds your dark, bias, and flat frames together. "Reference bias" subtracts the average of the counts due to reading out the CCD. "Dark subtraction" removes the thermal noise from your image frame. "Flat field" divides the image frame by the flat frame to remove differences in sensitivity between pixels in the CCD frame. Besides these basic functions, MIRA adds others to more precisely calibrate your image for the most exacting processing.

You can combine multiple exposures of the same field with the register function, a routine that's more sophisticated than that provided with many image-processing programs available to amateurs. It lets you shift, rotate, and magnify a frame to combine it with other frames. And if you want to join images together to make a larger frame, use the 2-D mosaic function.

The program can read ST-4, ST-6, Lynxx, and Photometrics CCD camera formats, as well as FITS, TIFF, and Voyager CD-ROM (PDS) file formats. It can store images in FITS and TIFF formats.

After calibrating the image, you can display it using a gray scale, a false-color palette, or true colors in the case of a tricolor image. Filters enable you to enhance images, remove noise, and fix errant pixel values. MIRA includes many high- and low-pass filters or you can design your own with the instructions given. Tools in the image display window enable you to zoom in and out, measure the distance between two points, change the brightness and contrast, and plot histograms showing the brightness of the pixels along a line or in a box. Other tools allow you to blink between two images, replace bad pixels by the median value of nearby ones, attach an equatorial coordinate system to the image, and read out equatorial coordinates instead of x and y pixel values. "Animate images" displays a series of images in succession. For instance, you could show a sequence of Jupiter images showing its rotation.

This is not an ordinary image-processing program designed for picture processing. It's a full-fledged program written for scientific image processing (but costs only as much as popular photo design programs). As such, it has a number of functions that permit magnitude determination, or photometry, of stars. You can choose between different photometry methods, such as annulus and curve-of-growth photometry, and then display lines of equal brightness (called isophotes) in an image of a galaxy, for example.

Despite its power, MIRA is relatively easy to use. An extensive manual explains not only how to use the program but how to apply the functions to images. The manual also tells you how to get the peak performance from your computer when manipulating large images. If you're tired of picture processing, want a powerful image-processing program, or need a program that can really handle lots of big images, look no further: MIRA can do it all. — *Dave Bruning*

NEW SOFTWARE

Galaxy Collisions
Jeff Alderman. To receive a copy, send a formatted diskette and a self-addressed, stamped diskette mailer to Galaxy Disk, ASTRONOMY magazine, P.O. Box 1612, Waukesha, WI 53187. Minimum requirements: IBM PC-com-

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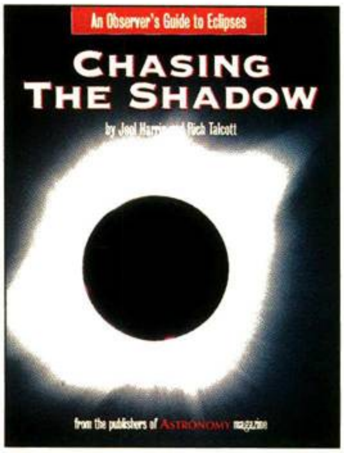
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This program is a new version of a GW-BASIC program published by Michael Schroeder and Neil Comins in the December 1988 ASTRONOMY. Schroeder and Comins' program is neat but a dinosaur by today's standards. GW-BASIC runs slowly and the user interface is a little primitive. Besides, who wants to type all the instructions in by hand anymore? Thanks to Jeff Alderman, now you don't have to. He rewrote the program in a compiled language for faster operation and added an easy-to-use interface for running it.

The program represents a galaxy as a number of particles. To control the type of collision between two galaxies you can enter their initial positions and velocities. At each step of the simulation, the program computes the gravitational forces on each particle by others in its galaxy and in the second galaxy. The resulting force determines how hard and in what direction to push the particle. Alderman's version can store simulations as an animation file so you can redisplay the simulation whenever you want.

Distant Suns (4.2) for Amiga
Virtual Reality Laboratories, 2341 Ganador Court, San Luis Obispo, CA 93401, (800) 829-8754. Price: $99.95. Minimum requirements: Amiga computer, two floppy disk drives, and 1 MB of memory. Accepts ARREX commands for running external programs, including telescope controls.

Distant Suns for the Amiga is a planetarium-type program that is similar to its PC and Mac cousins reviewed in April 1992 and March 1994. It displays stars, planets, constellations, and deep-sky objects for any date between 9999 B.C. and A.D. 9999. The program can animate the motions of planets or display an eclipse. The database contains 4,211 stars and more than 2,000 deep-sky objects. Optional databases extend the number of stars to 10,000, 20,000, or 250,000. For any date, a "What's Up" feature lists the planets visible, the lunar phase, meteor showers, and the rising and setting times of the Sun and Moon. Clicking on an object opens an identification box. For 21 objects, a button in the box enables you to view an image of the object. You can add your own images or purchase optional image sets. ☐

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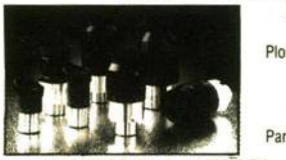

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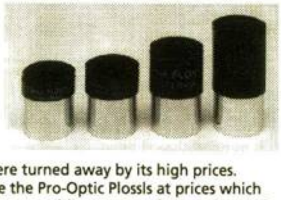

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Astronomical Enterprise	95
Astronomics	95
Astronomy Shoppe	96
Astro-Physics	27
AstroSystems, Inc.	78
Berger Brothers	96
Bethany Sciences	78
Black Forest Observatory	93
Blue Sky Pages	96, 97
California Telescope Co	95
Camera Bug	96
Celestron International	108
Central Camara Co	79
Compuscope	27
Computer Business Services	93
Cosmos Books	12
Coulter Optical Inc	92
Dew Remover System	79
Dino Productions	80
Eagle Optics	97
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Edmund Scientific Company	99
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Evaporated Metal Films	78
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Lire La Nature	97
Lumicon	17, 84, 85
Main Sequence	79
Marketplace, The	78, 79, 80
Meade Instruments	2, 3, 8, 9, 10, 11
MILA	79
Motion Control Systems	79
Mountain Skies Astronomical Society	80
Murnaghan	93
New England Meteoritical Services	94
New Mexico Astronomical	126
Newbridge Communications Inc	19
Nikon Sports Optics	13
Novagraphics	78
Nurnberg Scientific	96
Oceanside Photo & Telescope	96
Optical Guidance Systems	97
Orion Telescope Center	60, 61
Oxford University Press	15
Plenum Publishing Corp	87
Pocono Mountain Optics	12, 97, 101
Precision Optics	87
Rainbow Symphony, Inc	78
Reader's Exchange	104
Regency Cruises	94
Rivers Camera Shop	96
Sarasota Camera Exchange Inc	96
Science Connection	79
Science Source	79
Scope City	25
Sharpe Products Inc	16
Sherwoods Photo Ltd	97
Shutan Camera & Video	21
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Software Bisque	7
Software Systems Company	12
Spectra Astro-systems	27, 96
Star Gazer Steve	100
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Stellar Products	98
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Talbot Tours	16
Tech 2000	15
Technical Innovations	14
Tele Vue Optics, Inc	107
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ANNOUNCEMENT. Orange Coast College Observational Astronomy program seeks donations of telescopes and accessories to be used in our laboratory sections. Because of poor viewing conditions, we need telescopes 8" or larger. Donations are tax deductible. Contact Nick Contopoulos (714) 432-5846.

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WANTED. I'm getting bored with astronomy, but do not want to give up the hobby. I've gone about as far as I can without buying thousands of dollars more in equipment. Are there any aspects of astronomy I can use to rediscover my relationship with the sky? I'm hoping someone may be able to make suggestions. Contact Dr. Fred McCabe, 107 E. 12th Avenue, Emporia, KS 66801.

ANNOUNCEMENT. The Astronomical Society of Harrisburg in Pennsylvania meets at 7:30 p.m. on the second Monday of each month at the Museum of Scientific Discovery (October through April) and at the Lewisberry Observatory (May through September). For more information call David Mitsky, (717) 938-6041.

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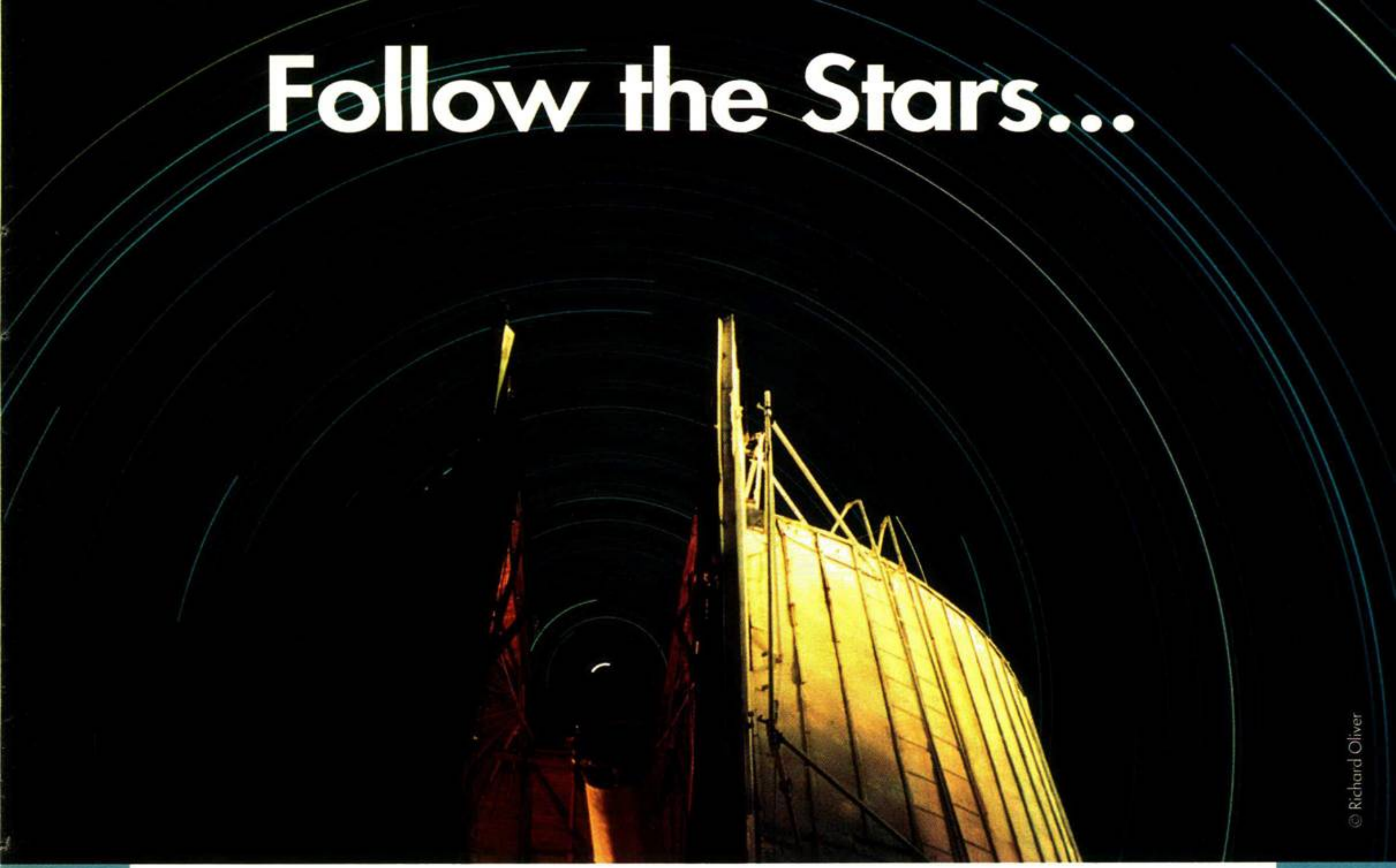

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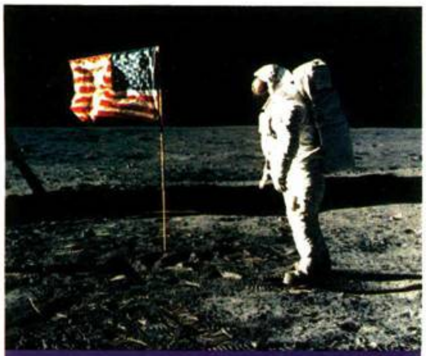

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READINGS & CREDITS

Countdown to the Big Comet Crash (page 40)

"High Impact Astrophotography" by Mark J. Coco, ASTRONOMY, April 1994. How to take detailed planetary photos.

"Jupiter's Magnificent Show" by José Olivarez, ASTRONOMY, April 1994. How to view Jupiter's belts and zones and sketch what you observe.

Tracking Down a Quasar (page 56)

A Handbook of Quasistellar and BL Lacertae Objects, by Eric R. Craine (Pachart, 1977). A superb guide that includes basic data, observational histories, and finder charts adapted from the Palomar Sky Survey for dozens of quasars brighter than 17th magnitude.

Uranometria 2000.0 by Wil Tirion, Barry Rappaport, and George Lovi, (Two vols., Willmann-Bell, 1988-1989). A detailed star atlas covering the northern and southern skies that includes the positions of hundreds of quasars.

Glittering Realms of the Summer Milky Way (page 62)

Stars and Galaxies; ASTRONOMY's Guide to Exploring the Cosmos, edited by David J. Eicher (Kalmbach, 1992). A reprint volume containing observational tips on 344 deep-sky objects, including many prominent objects from the summer Milky Way.

Beyond the Solar System: 100 Best Deep-Sky Objects for Amateur Astronomers, by David J. Eicher (Kalmbach, 1992). Includes all the great summer Milky Way targets.

Exploring Mare Humorum (page 70)

Atlas of the Moon by Antonín Rükl, edited by T. W. Rackham (Aventinum and Kalmbach, 1990). An authoritative atlas with detailed maps perfect for most amateur lunar observers.

The Moon: An Observing Guide for Small Telescopes by Michael T. Kitt, (Kalmbach, 1992). An up-to-date guide to the main lunar features visible in a small telescope.

Cover: Michael Stecker; **p. 4, left:** Frank Zullo; **top:** Steven Davis; Jupiter image/NASA; **middle:** Bill and Sally Fletcher; **bottom:** Jean Dragesco; **p. 5, middle:** Palomar Observatory; **p. 18:** Jeremy R. Walsh, ST-ECF, ESO; **p. 20, top:** © Anglo-Australian Observatory; **bottom:** STScI; p. 22, **top:** Alan Dyer; **bottom:** David L. Smith; **p. 24, top:** Naval Research Laboratory; **bottom:** Richard Walker, USNO; **p. 26, top:** Corning Incorporated; **bottom:** Chris Impey, University of Arizona; **pp. 28-39:** Bruce Bond; **p. 40:** illustration by Pat Rawlings; **pp. 41-42:** H. A. Weaver and T. E. Smith, STScI/NASA; **p. 42:** courtesy of Thomas Ahrens; **pp. 43-44:** illustration by Steven Davis, Jupiter image by NASA; **p. 48:** Charles Capen; **p. 51:** Keith Ward; **p. 53:** Paul Burke; **pp. 56-59:** Robert Wegner; **p. 57:** Palomar Observatory; **pp. 62-63:** Ronald E. Royer; **p. 63:** Palomar Observatory; **pp. 64-65:** Michael Stecker, 180mm lens at f/2.5, hypersensitized Tech Pan film, 60-minute exposure with a hydrogen-alpha filter; **p. 64:** Gerald Rhemann, 6.7-inch Schmidt camera, hypersensitized Ektar 25 film, composite photo made from two 20-minute exposures; **p. 65, middle:** Palomar Observatory; **bottom:** Jason Ware, 6-inch refractor; **p. 66:** Martin C. Germano, 50mm lens at f/4, hypersensitized Tech Pan film, 40-minute exposure; **p. 67, top:** Palomar Observatory; **middle:** Jack Newton, 20-inch f/5 reflector, Konica 3200 film, 20-minute exposure with a cold camera; **bottom:** Kim Zussman, 14.5-inch f/8 Cassegrain, hypersensitized Tech Pan film, 70-minute exposure; **pp. 68-69:** Ronald Royer and Steven Padilla; **p. 68, bottom:** Bill and Sally Fletcher, 16-inch f/4.5 reflector, tricolor composite made with three filtered, hypersensitized Tech Pan exposures: 35 minutes (red), 55 minutes (green), and 90 minutes (blue); **p. 69, top:** Palomar Observatory; **middle:** Michael Stecker, 180mm lens at f/2.5, hypersensitized Tech Pan film, 60-minute exposure with a hydrogen-alpha filter; **bottom:** George Greaney and Mike Newton, 14-inch SCT at f/7, hypersensitized Fuji Super HG 400 film, composite of two 50-minute exposures; **p. 70:** Gérard Therin, 9-inch SCT at f/12, Tech Pan 2415 film, 0.5-second exposure; **p. 71:** Jean Dragesco, 14-inch SCT at f/30, Tech Pan 2415 film, 2-second exposure; **pp. 72-77:** Frank Zullo; **p. 74, top:** Jim Forbes; **p. 81, top and center:** John Chumack and Glenn Gombert, 16-inch f/4.5 reflector, ST-6 CCD camera; **bottom:** Scott McAfee, 400 ISO film, taken on July 27, 1992; **p. 82, top left:** Jack Newton, 25-inch f/5 reflector, ST-6 CCD camera, taken on January 3, 1994; **bottom left:** John McNeal, taken in November 1993; **top right:** Douglas C. Brown, 50mm lens at f/2.8, Fuji Super HG 400 film, 10-minute exposure on November 29, 1993; **bottom right:** Dan Smiley, 8-inch SCT at f/6.3, Kodak Gold 100 film, 1-second exposure on January 12, 1994; **p. 83:** Carl Weber, 4-inch SCT, Kodak 400 ISO film, montage of 24 exposures taken on November 28-29, 1993; **p. 96:** Darla Evans. ☐

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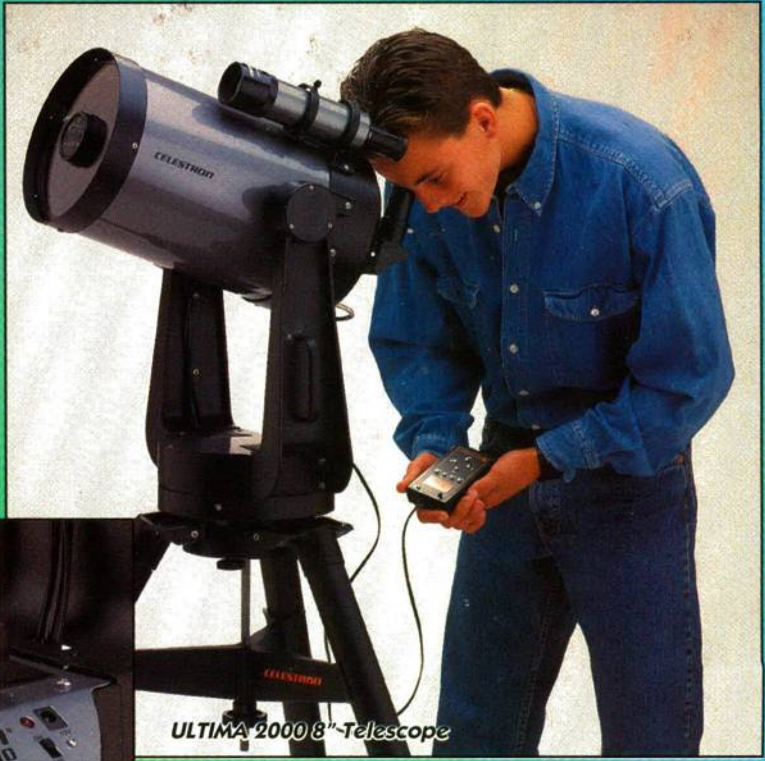

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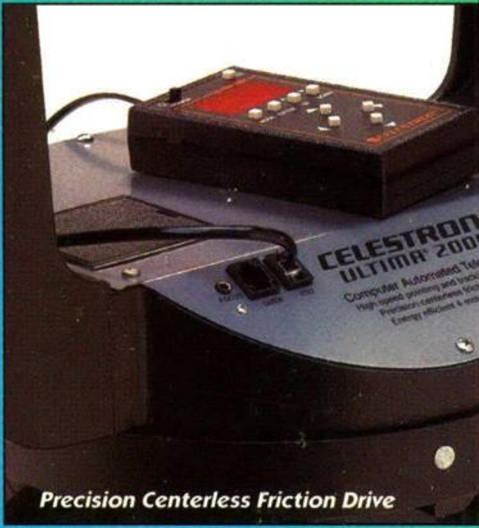

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